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Abstract

This deliverable reports on the work done in ADAM work package P3d. It examines the constraints and opportunities for mainstreaming adaptation to climate change in land use and water management in three study regions: the Guadiana River Basin in Spain and Portugal, the Tisza River Basin in Hungary and the Alxa region in western Inner Mongolia, China.

In all three regions, local populations are already experiencing the impacts of a changing climate. New climate projections are being made available, contributing to regional and political awareness of potential climate risks. So far the primary focus of academic analysis has been on temperature. Improved projections, especially of precipitation and climate related risks like water shortage, remain important challenges. These projections depend critically on the scale and the resolution of the data used as well as on integration of social and political aspects in the evaluation of potential adaptation strategies.

At present pro-active adaptation actions are planned for future climate change, yet on a limited basis. Adaptation is mostly in the planning stage or implemented through pilot projects. There is no clear connection between regional climate impact studies and adaptation planning. Adaptation planning typically accounts for more general climate trends and scenarios, partly because detailed assessments of climate impacts have only recently become available. Although climate change has encouraged dialogue between different actors and policy communities (for example water and agriculture), actual adaptation planning and implementation remain largely sectoral. So far, the impact of adaptation mainstreaming on the integration of non-climate policies is limited in our study regions.

While there are substantial constraints to adaptation there are also opportunities emerging. These were analysed along to the following aspects:

Biophysical aspects: In all three regions, ecosystems have degraded and water resources are heavily exploited. Traditional landscape and resource use practices, such as the traditional floodplain production systems in the Tisza, had an active role in regulating climate extremes. This regulating service has motivated local populations, scientists and policy makers to explore the traditional agro-ecological production systems. Our research in the Tisza and Guadiana river basins show that preserving and managing diversification of land use has a great potential for reducing climate related risks.

Technical aspects: Existing technical solutions, like building dikes, run into limits or add to undesirable and/or longer-term effects. Pilot projects and demonstration activities have started to test the feasibility of new technologies. There is scope for the development and exchange of more sustainable technologies and information systems, including early warning systems (e.g. the cell phone based warning service in Inner Mongolia). Currently available integrated assessment models are not parameterised for assessing new technologies and more complex and innovative adaptation strategies, creating a barrier for the appraisal of mainstreaming.

Financial aspects: Financial resources are limited in each of the study regions and adaptation is often considered too costly and uncertain compared to expected benefits. Whereas there is a pressure on existing financial services (like insurance) to become more expensive, new financial instruments are also emerging (e.g. micro-grants). The implementation of adaptation strategies is constrained by unequal distribution of costs and benefits. For instance, measures taken to reduce land degradation and sand storms may be financially unsustainable, and water retention increases risks for those who store the water for the benefits of others. Mainstreaming adaptation complicates existing relations with donors or financial instruments. The European agro-environmental schemes for example, are not designed for inter-annual land use changes, driven by water availability. Creating markets for adaptation is a key challenge. All three regions identified opportunities for public-private partnerships in which marketable products obtain additional support in exchange for providing social and environmental services that support adaptation.

Institutional aspects: Divided, changing or unclear responsibilities are key constraints for adaptation actions in the Guadiana and the Tisza river basins. By contrast, in Inner Mongolia, the rigidity of the strictly defined roles of different organisations is considered a constraint, as is the limited communication of intended policy goals to beneficiaries. Stable adaptive governance is a complicated paradox. Adaptive governance is a relatively new concept that needs to be demonstrated to gain in appreciation. Inspiring examples are the emerging coalitions of government and non-government actors that are helping to put the adaptation agenda in a regional context and encouraging action in the region. Successful coalitions often have close connections to academics who act as brokers in the communication of climate risk and adaptation information. Our analysis in the Tisza region shows the importance of recognition of adaptation at an abstract level by responsible civil servants and advocation of an adaptation strategy by a credible regional coalition. The recognition of adaptation and political attention following a number of major (near) floods, provided a window of opportunity for changing land use and water management. Opposition is inherent to implementing more fundamental policy change and engaging with (potential) opponents is an important activity in adaptation planning.

Social aspects: Adaptation can fail or be counterproductive because social processes and structures are imperfectly understood. In the Tisza basin, for example, sites for water retention were rejected. In the Alxa region, the enclosure of livestock conflicts with traditional lifestyles. The Tisza study region shows that informal social networks around local production systems have degraded, but are remediable. Local populations hold a wealth of knowledge on how to cope with climate variability, which deserves to be taken into account while developing new policies and measures.

Cognitive and informational aspects: In the Alxa and Guadiana regions in particular people struggle to connect regional trends to global climate change. The causes of trends in desertification and reduced water availability are heavily contested. Adaptation policy so far does not address the diverse perceptions of risks and their causes. The Tisza region shows benefits of debating climate related risks and how best to respond; after various discussions on adaptation options, actors were quick to take advantage of a micro-grant scheme for implementing local solutions. This supports the notion of adaptation as a social learning process. All three regions suffer from a lack of (access to) information about climate impacts and adaptation options and policies. Newly emerging forums for debating adaptation strategies may prove to be valuable in this regard. At the regional level these are often associated with internationally funded projects. Yet, a gap remains between scientific adaptation theory and adaptation practice on the ground. There is a mismatch between model assessments of impacts and adaptation on one hand and 'real' adaptation options as discussed by people in the region or in the policy plans on the other.

Our research suggests that all six aspects of adaptation discussed above are needed to capitalise on opportunities for successfully planning and implementing adaptation. Institutional and cognitive aspects have been identified as particularly important, but the relative weight of each aspect depends on location and will vary over time. Furthermore we argue that in the long term, building capacity to adapt to climate change will depend on the extent to which climate concerns are integrated into the planning and implementation of land use and water management. Based on our empirical findings we provide recommendations that could facilitate such climate mainstreaming. We find that adaptation is enhanced by

i) adaptation pilot projects that test and debate a diverse set of new ideas in a collaboration of civil society, policy and science;
ii) open and easy access to information on climate impacts, policy and adaptation options;
iii) space for debating and learning;
iv) integration of (traditional) agro-environmental land use systems that regulate climate impacts at the local and regional scale with new technologies, policies, organisational responsibilities and financial instruments; and
v) flexible financial instruments that facilitate benefit and burden sharing, social learning and support a diverse set of potentially better-adapted new activities rather than compensate for climate impacts on existing activities.

Results from the final workshops and background studies carried under the work package P3d in cooperation with other ADAM partners are included in Chapter 3 to 5.

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Dedicated to the late Prof Zsolt Harnos, leader the Corvinus University team for ADAM

1 Introduction

Since initial work for the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (2001) demonstrated that adaptation is both important and complex, there has been growing attention for documenting adaptations as they happen and explaining the processes by which adaptation can occur, hopefully successfully (Adger *et al.*, 2005b; Adger *et al.*, 2007). Whereas the literature on adaptation is rich in detail on impacts, vulnerability and limits to adaptation, less is known on the conditions that facilitate adaptation in practice (McEvoy *et al.*, 2008). The latter is, however, of paramount importance for developing integrated guidance on how to cope with climate change in the long term.

This report applies the definitions and concepts of impacts, vulnerability and adaptation as outlined by the IPCC (Adger *et al.*, 2007) and examines adaptation practices in the context of climate impacts and vulnerability. Adaptation to climate change takes place through adjustments in human and natural systems to reduce vulnerability in response to observed or expected changes in climate and associated extreme weather events. It involves changes in perceptions of climate risk and in social and environmental processes, practices and functions to reduce potential damages or to take advantage of new opportunities. It includes anticipatory and reactive actions, as well as private and public initiatives. In practice, adaptation is an on-going process, reflecting multiple stresses and cross-sectoral concerns, including discrete actions to address climate change specifically. Isoard and Swart (2008) conclude that human adaptation occurs mainly at sub-national and local levels but involves many other levels of decision-making from municipalities to international organisations. Adaptation is a cross-sectoral, multi-scale and transboundary issue, which requires a comprehensive and integrated response.

Societies have always had to respond to regional climate variability and extreme weather events. Many have developed ways of coping with floods, fires, heat waves and droughts (for instance, the vernacular architecture of Mediterranean countries). Recent experience of weather extremes has given these efforts new impetus within countries as well as at the European level. Whilst climate change is a new driver for action, adaptation will in many cases be implemented by regulatory modifications of the existing policy frameworks for floods, droughts, rural development and water management. Step-wise advances in action, coordination and engagement of agents at the local and regional level will be needed to handle the expected level of accumulated incremental change over time, and to address the increased possibility of new extreme events (Footitt and McKenzie Hedger, 2007). Following Klein (2007), we use the term mainstreaming for the step-wise integration of adaptation policies and measures into ongoing sectoral planning and decision-making to reduce climate vulnerability and ensure long-term sustainability.

Land and water resources are directly impacted by climate change, and decisions regarding these resources affect ecosystems and human vulnerability. In rural contexts, land use planning and water management are expected to play an increasingly central role in adaptation strategy. Stern (2006) identifies land-use planning as a key area for adaptation. Yet, although changing land use planning is a promising adaptation strategy to cope with climate change impacts, this strategy is not practised extensively (Footitt and McKenzie Hedger, 2007). The multitude of land uses and stakeholders make land use and water management complex sectors in the climate change arena that deserve special attention. So far climate change analyses and climate policy formulations have not adequately addressed the integration of water resource issues and climate change response options, including associated synergies and trade-offs between different policy domains and scales of action (Bates *et al.*, 2008).

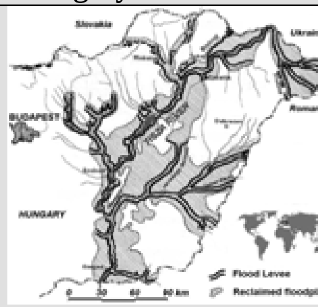
This report examines the challenges and opportunities for adaptation to climate change in the three study regions of work package P3d of the ADAM project: the Guadiana River Basin in Spain and Portugal, the Tisza River Basin in Hungary and the Alxa region in western Inner Mongolia, China[1]. The three regions share that they increasingly struggle with climate impacts on land use and water resources, including desertification and the occurrence of extreme events such as floods and droughts. However, the institutional contexts and governance traditions upon which societal responses and adaptation practices have developed differ greatly in the three regions. We examine adaptation practices from a comparative, empirical and analytical perspective, before synthesising this information to sharpen our understanding of the constraints and opportunities for the successful implementation of adaptation through land use and water management policies and practices. In particular, the research in the three study regions is synthesised according to: i) climate change and impacts on land use and water management, ii) adaptation practices to climate variability and change; and iii) constraints and opportunities for enhancing adaptation as a response strategy for climate change. Chapter 3 to 5 contains the results from the final workshops and background studies carried out under work package P3d in cooperation with other ADAM partners. These studies were defined in the scoping phase and first workshops of the work package (ADAM Project, 2007a; ADAM Project, 2007b; ADAM Project, 2008b) around two main questions (ADAM Project, 2008a): 1) *What are adaptation challenges and opportunities in regional land use and water management? 2) What institutional setting facilitates mainstreaming adaptation into integrated water and land management*? The report closes with a discussion of the lessons learned from the study regions for mainstreaming and furthering adaptation through land use and water management.

[1] The ADAM project sought Chinese research cooperation to enrich the project with non-European perspectives and to acknowledge the international dimension of climate change impacts and greenhouse gas emissions. Within China, the Alxa region in Inner Mongolia was selected as a case of significant climate related land use change of great national concern.

2 Overview of adaptation practice in the three study regions

In order to analyse the conditions that facilitate or limit adaptation in the three case study regions of the ADAM project regions, we first briefly introduce the biophysical and institutional context in which adaptation is taking or needs to take place. In particular we look at the potential impacts of climate change in relation to land use and water management. Second we describe adaptation practices in each region as identified by the ADAM project through workshops, interviews with stakeholders, background studies and a review of secondary sources. Finally, we discuss the constraints and opportunities to adaptation according to six dimensions: 1) Biophysical, 2) Technical, 3) Financial, 4) Institutional, 5) Social, and 6) Cognitive and Informational[2] (cf. Smit and Pilifosova, 2001; Adger *et al.*, 2005a; Adger *et al.*, 2007; Bates *et al.*, 2008). Table 2.1 summarises the main characteristics of the three study regions.

Table 2.1: Characteristics of the three study regions

	Guadiana Region, Spain & Portugal	Alxa Region, Inner Mongolia, China	Tisza Region, Hungary
			
			
Biophysical, land-use	Semi-arid climate, forest, agriculture	Arid climate, desert, livestock, agriculture	Continental climate, grassland, agriculture
Climate projection	Significant temperature increase,rainfall decrease	Temperature increase, rainfall trend uncertain	Temperature increase, rainfall more irregular
Area / Arable land	66,800 km^2 / 20 million ha	270,000 km^2 (main study area 72,000 km^2) / 30,000 ha + 9 million ha steppe	46,000 km^2 (Hungarian part river basin) / 2.6 million ha
Technical	2000 dams. Reservoir and irrigation system	Irrigation, groundwater and water transfers	2800 km river dike, drainage system

[2] The cognitive dimension includes aspects of recognition (the ability to recognise the challenge), reflexivity (the ability of people and organisations to reflect on and adapt their behaviour), and perception/framing (legitimately-diverse views about risks, vulnerability and adaptive capacity).

	Guadiana Region, Spain & Portugal	Alxa Region, Inner Mongolia, China	Tisza Region, Hungary
Economic	Participation in EU and global market. Tourism. GDP 20,000 per capita Below EU average	Increasing market forces and industrialisation. GDP 2,000 euro per capita	Transition economy. GDP: 4,500 euro per capita. Below country average
Institutiona l	EU member since 1986. EU regulation. Regional competences defined in Spain and Portugal	Communist party-led state; well defined limited regional autonomy	EU member since 2004. Implementation national and EU regulations
Social	4 million people. Aging	200,000 people. Mongol minority	4.1 million people. Roma minority

2.1 Guadiana River Basin

2.1.1 Climate change and impacts on land use and water management

The Guadiana is a transboundary river between Spain and Portugal. Its basin is one of the three main drainage units of the Iberian Peninsula. Eighty-three percent of the basin is located in Spain and seventeen percent is in Portugal (Henriques Goncalves, 2005). The river basin has the typical semi-arid climate of Southern Europe with low and irregular precipitation (440 mm/year). Rainfall peaks in the central-north, decreasing westwards towards the mouth of the river (Orioli *et al.*, 2008). Average seasonal temperature ranges from 14.5 degrees Celsius (winter) to 31.9 degrees (summer). Temperature rarely drops below zero. Climate scenarios projects a temperature rise in spring and summer of four to seven degrees by 2100 (Santos *et al.*, 2002), with temperature variation increasing towards the north east of the basin. At the same time rainfall is expected to decrease in spring and in summer. Figure 2.1 illustrates this using the SRES A2 Scenario results from the HIRHAM model (Extra High Resolution: 12.5 x 12.5 km) (Orioli *et al.*, 2008). The natural hydrological regime of the Guadiana is characterised by low flows during summer and confined high flow events in winter. Using the HadCM3 model's climate scenarios, annual runoff is estimated to fall by sixty percent by 2100 (Santos *et al.*, 2002).

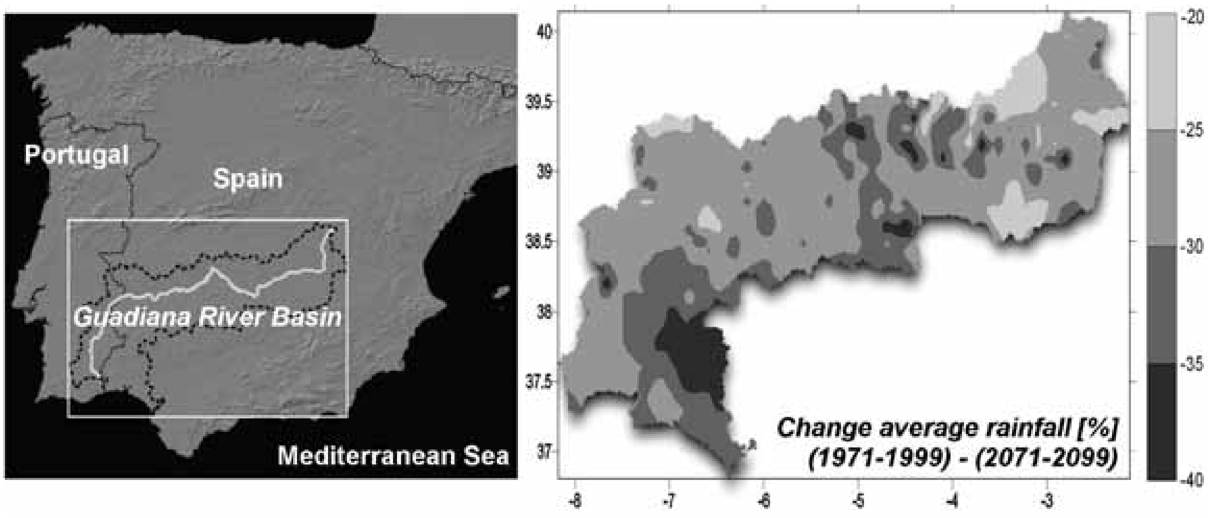


Figure 2.1: Guadiana River Basin and projected change in average summer precipitation between 1971-1999 and 2071-2099 in SRES Scenario A2 using regional climate model HIRHAM (adapted from Orioli *et al.,* 2008)

In the last four decades, the river basin has undergone major modifications through the building of dams, tourism developments, (illegal) wells and increasing urbanization pressures. On the Portuguese side of the basin the Alqueva dam has been built. This created the largest artificial lake in Europe for which water use is still to be allocated. In the Spanish Upper Guadiana basin, whilst groundwater development has substantially increased people's livelihoods, groundwater use is not sustainable and groundwater tables are falling. The main problems associated with land use and water management are overexploitation of aquifers for agricultural use, agricultural contamination and river fragmentation by dams (Cosme *et al.*, 2003; WWF, 2003; Tàbara *et al.*, 2009). The combination of these developments and the semi-arid climatic conditions has intensified water scarcity along the Portuguese-Spanish border. Climate change potentially increases the pressure on available resources and conflicts between agriculture, irrigation, tourism, nature conservation and the development of large urban areas. Furthermore, climate change impact assessments show a worsening of the current situation of desertification, particularly through the impact of forest fires (Moriondo *et al.*, 2006) and the loss of soil fertility (ECCE Project, 2005).

Land use and agricultural practice differs considerably in the region. Going from southwest to northeast three main zones can be distinguished. The first zone is the coastal zone with mainly tourism on the Portuguese side (Algarve) and a combination of intensive agriculture (mostly citrus and fruits) and tourism on the Spanish side. Moving inland, the next zone is hilly, forested and supports a unique ecosystem called *dehesa* (Spanish) or *montado* (Portuguese). Dehesa farmers combine cork oak (*Quercus Suber*) and common oak (*Quercus robur*) with different types of tree crops (olives, figs, almond, oranges, carobs), ground vegetation (cereal, herbs, grass) and cattle breeding (cows, sheep, red swine) (Joffre *et al.*, 1999). Dehesa has a high landscape value and is protected as cultural heritage. The third zone is dominated by large-scale agriculture (Beja region in Portugal and Extremadura in Spain). Crops include cereals, wine, olives and citrus. Crops are grown both irrigated and non-irrigated. The share of irrigated land is expected to change in part due to the new Alqueva reservoir.

The impacts of climate change depend strongly on the cropping system. Dehesa is well adapted to the regional climatic conditions, although its economical feasibility is questioned (Joffre *et al.*, 1999). With respect to intensive agriculture the impacts differ for summer and winter crops[3]. Climate change is not expected to significantly impact winter wheat and spring wheat. The summer crops sunflower, soybean and corn are projected to be the most adversely affected crops with consistent reduction in yield in almost the whole basin (on average fifteen, thirty and thirty-five percent respectively) (see Section 3.2; work in cooperation with work package A2). By

[3] The impacts of climate change on crop yields were simulated for five different crops using a crop growth simulation model (CropSyst). Crops were selected to include a winter crop (winter wheat) and four spring-summer crops (spring wheat, sunflower, soybean and corn). Present and future crop yields were simulated under the SRES climate scenario A2. Corn was the only crop that was always irrigated in the simulations. Extreme events (heat stress due to heat waves, water stress during droughts) were included as further threats to production.

affecting crops differently, climate change will also affect the robustness of cropping patterns (Werners *et al.*, 2007b).

2.1.2 Assessment of adaptation practices

Stakeholders proposed the following adaptation options in relation to land use and water management[4] (ADAM Project, 2007c; Tàbara, 2007): agricultural and economic diversification, changing farm size, reuse of grey water, promotion of rural tourism and local produce, and protecting as well as modernising the 'dehesa' agro-ecological production system, using (new) drought and heat resistant crops (e.g. dates) and (changing) irrigation systems. Reforestation was welcomed as an adaptation option though criticism was voiced with respect to the current use of fire prone pine species. Next to biophysical interventions, stakeholders emphasised the need for building adaptive capacity at the farm and regional institutional level, through awareness raising, better coordination between actors and policies, and financial support for promoting alternative sustainable activities (often linked to small-scale rural tourism and businesses).

Figure 2.2: Guadiana River Basin: a) Guadiana River at Mertola, Portugal, b) Extensive agro-environmental production system dehesa, c) Intensive irrigated agriculture, d) Tourism development in the estuary (Photos: Werners, Dec 2006).

Changes in climate institutional arrangements can be observed in both countries and in particular at the river basin scale although still in an early stage (McEvoy *et al.*, 2007). Arrangements that affect the Guadiana River Basin include the Portuguese National Climate Change Programme (2001) and the Spanish National Adaptation Plan (2006). Implementation of these programs is

[4] Interviews in Seville and Mertola, fieldtrip and workshop held in Mertola, Portugal; 12 – 22 December 2006

the responsibility of several newly created national bodies, such as the Portuguese Climate Change Commission, the Spanish Inter-ministerial Group on Climate Change and the National Council on Climate Change. Among their duties is to promote climate change policy across government and to ensure integration of climate considerations into sectoral and regional policies in accordance with national and European regulation. These new bodies are also required to ensure the participation of public and private actors in the policy making process (see Section 3.5).

With agriculture an important economic sector in the region, the ADAM project assessed different agro-technical adaptation measures for field crops (see Section 3.2). The results listed in Table 2.2 show that irrigation and changing crop variety for a shorter growth cycle are the most promising of the assessed measures. This concurs with opinions held by stakeholders. At the same time, Table 2.2 suggests that the effectiveness of each adaptation measure depends strongly on crop type and that some measures could even be counter productive with respect to crop yield. Together with the potential pressure of irrigation on the already strained water resources, this highlights the potential for mal-adaptation.

Tourism is another important sector in the Guadiana region. ADAM research highlighted the close interplay between tourism and other important sectors, such as agriculture and water supply, finding that the promotion of more sustainable forms of tourism is not only more fitting for the natural landscape, but is also considered to have the potential to support local livelihoods in the future. Indeed, many of the regional landscapes that appeal to visitors are currently managed by traditional agricultural practice, and a greater emphasis on the multi-functionality of the land (bringing together tourism, nature and agricultural concerns) could be of significant benefit to the adaptation agenda. It would help strengthening long-term sustainable development objectives for the region as well as reducing over-dependence on one economic activity (see Section 3.3).

Table 2.2: Effectiveness of selected field crop adaptation measures

Adaptation measure	*Winter wheat*	*Spring wheat*	*Sun-flower*	*Soy-beans*	*Corn*
Shift in sowing date (±15 days relative to 'no adaptation')	😐	☹	☹☹	☹	☺☺
Irrigation (of those crops that are non-irrigated under 'no adaptation')	☺	☺	☺☺	☹	*)
Changed growth cycle (±20 % for each growth phase duration relative to 'no adaptation')					
Shorter growth cycle (-20%)	☹	☹	☺☺	😐	☺☺
Longer growth cycle (+20%)	😐	☹☹	☹☹	☹☹	😐

☺☺: 10 – 25 percent gain of crop yield; ☺: around five percent yield gain; 😐: no gain or loss; ☹: around five percent yield loss; ☹☹: 10 – 25 percent yield loss relative to 'no adaptation'.
*) Not included as adaptation strategy as corn is always irrigated in simulations

2.1.3 Enhancing adaptation - constraints and opportunities

A limiting factor to the analysis of adaptation in land use and water management is the sectoral and disciplinary perspective with which adaptation measures are often assessed. Mainstreaming requires an understanding of economic aspects, such as market trends, cost of inputs and new incentives for agriculture, as well as institutional and plant specific physiological aspects. These multiple dimensions of the adaptation challenge have yet to be addressed comprehensively. More complex production systems like dehesa and diverse cropping patterns offer opportunities to reduce climate risks (Werners *et al.*, 2007b).

To implement adaptation actions, stakeholders underlined the importance of cooperation between administrative agencies of both countries to ensure integrated socio-ecological planning in the Guadiana River Basin (ADAM Project, 2007c). According to Cots *et al.* (2007) a promising administrative vehicle for mainstreaming climate concern into the already existing regulatory transboundary cooperation is the "Convention on Cooperation for the Protection and Sustainable Use of the Portuguese-Spanish River Basins" (1998) and its Commission for the Convention Development and Application (CDAC). The Convention defines the regulatory framework for cooperation between the two countries to protect inland waters (surface waters and groundwater) and their dependent ecosystems and to use the shared basins waters sustainably. The experience from the Guadiana study region suggests that a transboundary organisation like the CDAC can break down regional or national divisions while at the same time foster new cooperation and collaboration because i) it works on the scale of the transboundary river basin, ii) it facilitates participation by providing a space for exchange between actors on both sides of the border and iii) it intervenes in a broad set of activities and regulatory areas. However, three main obstacles remain: explicit climate change considerations are absent in the convention, its implementation lacks transparency and participation, and both the Convention itself and the work of the Commission for the Implementation and Development of the Convention are almost unknown to the general public and even to the local administrative bodies in the Guadiana basin (Timmerman and Doze, 2005).

An important opportunity for adaptation in the Guadiana basin is the harmonisation and implementation of the European regulatory framework. The implementation of the Water Framework Directive (Commission of the European Communities, 2000) and the new EU regulatory processes in the field of river basin and water resources -such as the EU Floods Directive, the White Paper on Adaptation and the EC communication on Water Scarcity and Drought- provide added stimulus for new transboundary governance structures. Regions have gradually developed a more important role both in the European and the national arena (Jones and Keating, 1995). Today, regions interact directly with EU bodies to obtain resources from the distributive policies and further their interests. As a transboundary region, the Guadiana River Basin is eligible for the European INTERREG and Structural Funds that promote transnational networks and the definition of common interests and co-operation (Tàbara *et al.*, 2009). This said, the review of the Spanish National Adaptation Plan in 2008 revealed that adaptation policies were still underdeveloped, particularly at river basin scale, while regional policy makers argue that a more harmonised EU policy framework is needed to take decisive adaptive measures in the various potentially affected sectors.

Changes in policies and institutional designs are not only motivated by European policies. Evidence from the study region also suggests an increasing 'bottom up' influence as indicated by a gradual increase in the involvement of local actors who were typically excluded from the policy making process. Programmes and policies that deal with adaptation to climate change are emerging at the regional and national level. The inclusion of other relevant policies, actors and governmental levels can strengthen these programs and help with the coordination of objectives and policies aimed at long-term sustainability. The wide range of policies and actors that directly or indirectly influence adaptation in the Guadiana River Basin indicate the importance of building capacity among local, regional and national actors -both public and private- for mainstreaming (see Section 3.3 and 3.6).

Table 2.3 summarises constraints and opportunities for climate adaptation that were identified in the Guadiana River Basin study region.

Table 2.3: Constraints and opportunities for climate adaptation in the Guadiana River Basin

	Constraints	Opportunities
Biophysical	Water resources (especially groundwater) already over exploited	Revalorisation of landscape diversity and dehesa ecosystem services
Technical	Highly controlled river flow	Water saving technologies and crop modification
Financial	Large sunk costs of existing water infrastructure. Subsidies indirectly increase climate risks (e.g. subsidised reforestation with pine trees increases forest fires)	European funds encouraging cross-border regional cooperation and economic diversification, e.g. rural tourism to make farmer's income less climate dependent
Institutional	Existing procedures for water allocation are contested. Adaptation policies largely unknown to general public, with limited participation in implementation	Implementation of European guidelines and directives are a driver for transnational networks of different national and sub-national agencies
Social	Pressure on available water resources increases conflicts between land and water users	Tradition of living in drought prone area. Tourism market for local products and customs
Cognitive and Informational	Climate change not main concern. Suitability of traditional agro-environmental systems under climate change contested. Limited access to information on climate scenarios and adaptation options	Regional institutes start to embrace climate change and adaptation as a topic and provide contextualised climate information. European policy, directives and research encourage discourse on climate, land use and water management

2.2 Inner Mongolia Alxa Region

2.2.1 Climate change and impacts on land use and water management

The Alxa region in Inner Mongolia covers more than 270,000 km^2 of Northern China and is characterized by a continental arid to semi-arid temperate desert to steppe ecosystem. The average temperature is seven degrees Celsius with extremely cold winters and very hot summers. Precipitation ranges from 50 mm in the Northwest to 200 mm in the Southeast with high spatial and interannual variability. Hence water availability is a critical environmental factor (see Section 4.3). Temperature has risen since the 1950s, and regional climate models project a further rise, ranging from three to five degrees Celsius above pre-industrial values by 2100, depending on the scenario (Xu *et al.*, 2006). As a result surface evapotranspiration will increase, placing extra pressure on water availability. Projected precipitation changes are more uncertain and differ largely between climate models as rainfall is scarce and small absolute changes may correspond with large relative changes (Xu *et al.*, 2005) (Figure 2.3). In addition, some models suggest an increase in precipitation and a cooling trend for some areas (ADAM Project, 2008b) adding to the uncertainty adaptation policy has to cope with.

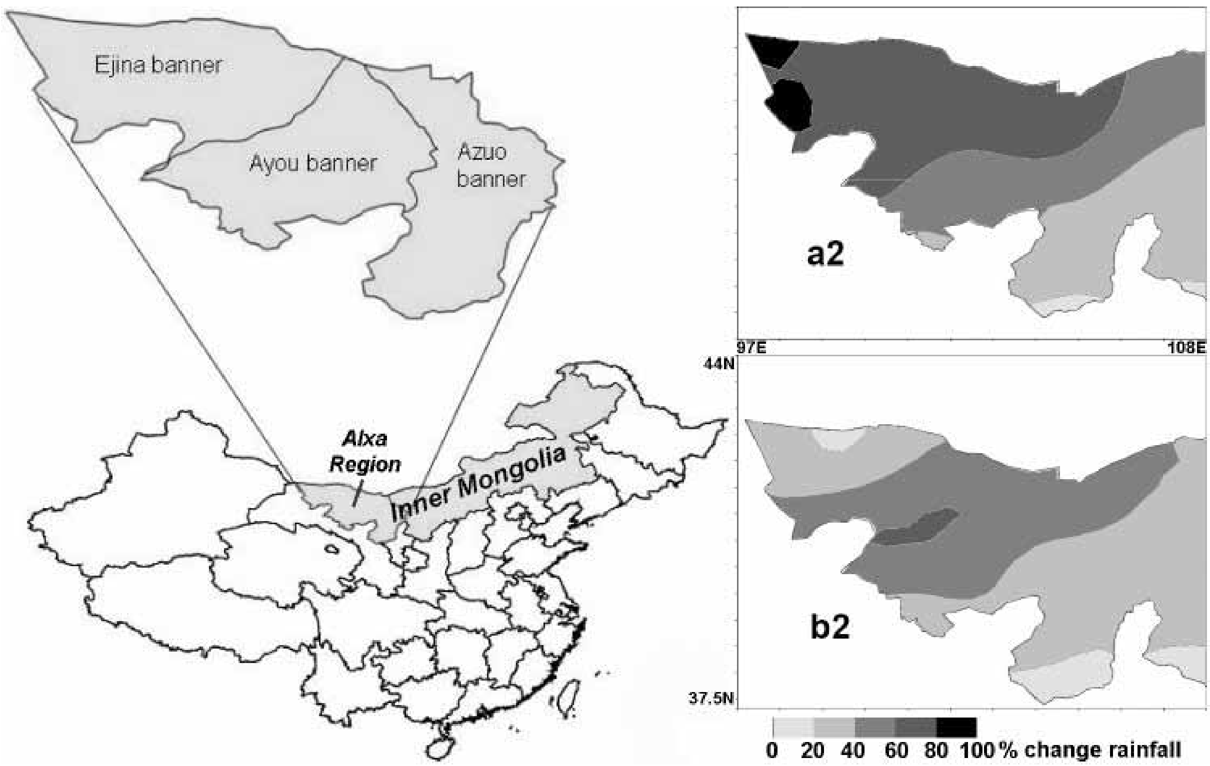


Figure 2.3: Alxa region in Inner Mongolia, China and projected change in average precipitation between current and SRES scenario A2 and B2 (2071-2100) using regional climate model PRECIS (after Xu *et al.*, 2005).

Traditionally the Mongol lifestyle was one of nomadic pastoralism (Dickinson and Webber, 2007). The immigration of Han Chinese and Mongolian farmers brought farming practice from outside Inner Mongolia to the region. Since these changes, many herders have given up their nomadic lifestyles and established permanent dwellings, as recommended by government policy in view of desertification and population growth (see Section 4.2 and 4.6). This meant that pastures are no longer grazed in rotation as previously, but used intensively all year round (Brogaard and Zhao, 2002).

Nowadays most of Alxa's nearly 200,000 inhabitants live in small towns in close proximity to the hundreds of desert oases. Water availability is low (110 m^3/ capita year, five percent of the national average). The main land use is irrigated agriculture and extensive rangeland. Currently, rangeland covers one third of Alxa with an official livestock population of 2,200,000, managed by 30,000 herdsmen (see Section 4.2). Use of lands at the margin of deserts, conversion of rangeland, increasing animal numbers in the 1980s and 1990s, and changing herd composition[5] are officially cited as the key human driving forces of recent desertification (Dickinson and Webber, 2007). More than sixty-five percent of the rangeland in Alxa is currently classified as degraded, resulting in an estimated productivity reduction of twenty-five percent in the past 20 years. The reasons interviewees gave for desertification included both climatic variation (reduced precipitation and warmer winters) and increasing livestock numbers due to general government reforms implemented after 1978 that encouraged private livestock ownership (cf. Brogaard and Seaquist, 2005; West, 2009) (see Section 4.6). Over eighty percent of the farmers and herdsmen interviewed in the Alxa region have noticed a decline in water quantity and quality as well as an increase of severe droughts and heat waves (see Section 4.7). Interestingly, only a few of those interviewed associated these changes with global climate change (Dai *et al.*, 2008).

Desertification has connected three formerly distinct deserts (Badain Jaran, Tengger and Ulan Buh), resulting in more intense sand storm events[6] and the abandonment of approximately half the human settlements in the affected region (Du and Huang, 2005). The sandstorms cause serious economic loss and ensure that impacts are not confined to the region but also adversely affect other areas (including countries as far away as Japan and South Korea), giving the problem an international dimension (ADB, 2005).

2.2.2 Assessment of adaptation practices

Although the key drivers of the desertification problem are disputed, it is acknowledged that climate change can amplify existing problems (Reynolds *et al.*, 2007). Analysis of measures and policies to deal with desertification and environmental degradation can therefore provide useful insights into the constraints and opportunities for adaptation practice in China. While the intensification of sand storms caused concerns in the region it also raised government awareness about desertification (Kar and Takeuchi, 2004). Policies aimed at rangeland rehabilitation have sought to address the biophysical, as well as the social and economic aspects of desertification (see Section 4.2). Examples of land use policies are grassland enclosure, grazing bans, promotion of land conversion on sloped lands (the so-called "Grain for Green" policy (Du, 2006)), logging

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[5] Primarily due to the economic value of cashmere, the composition of herd has shifted from a mix of horses, camels, cattle, sheep and goats, to overwhelmingly sheep and goats. While having lower water requirements, by exposing or pulling out roots they are also more destructive to the grassland.

[6] Trends in sandstorm frequency are contested. Over the last two decades strength and frequency rose. Since 2006 the strength intensified further, but the frequency declined.

bans, and tree planting. Socio-economic policies include general poverty alleviation strategies (for example the "Eight-Seven" Poverty Alleviation Reinforcement Plan (1994-2000)[7]) and herdsmen resettlement programs, in China referred to as ecological migration[8]. Ecological migration in Alxa has resulted in the migration of 6,624 households (approximately 25,000 peasants and herders) in five years (Du and Huang, 2005) (see Section 4.6). The Alxa development plan aims to reduce by 2010 the population living on extensive livestock grazing by two thirds. It is intended that this goal will mainly be achieved by providing job opportunities in the coal mining and chemical industry sectors that have developed rapidly in northeast Alxa in recent years under the Grand Development in West China programme (Yan and Quian, 2004). Since the introduction of rangeland rehabilitation in 2001 about twenty percent of the rangeland has been closed throughout the year and another thirty percent has been put under rotational or seasonal grazing. In the areas under protection there is localised evidence of vegetation recovery (see Section 4.2) (Dai *et al.*, 2008).

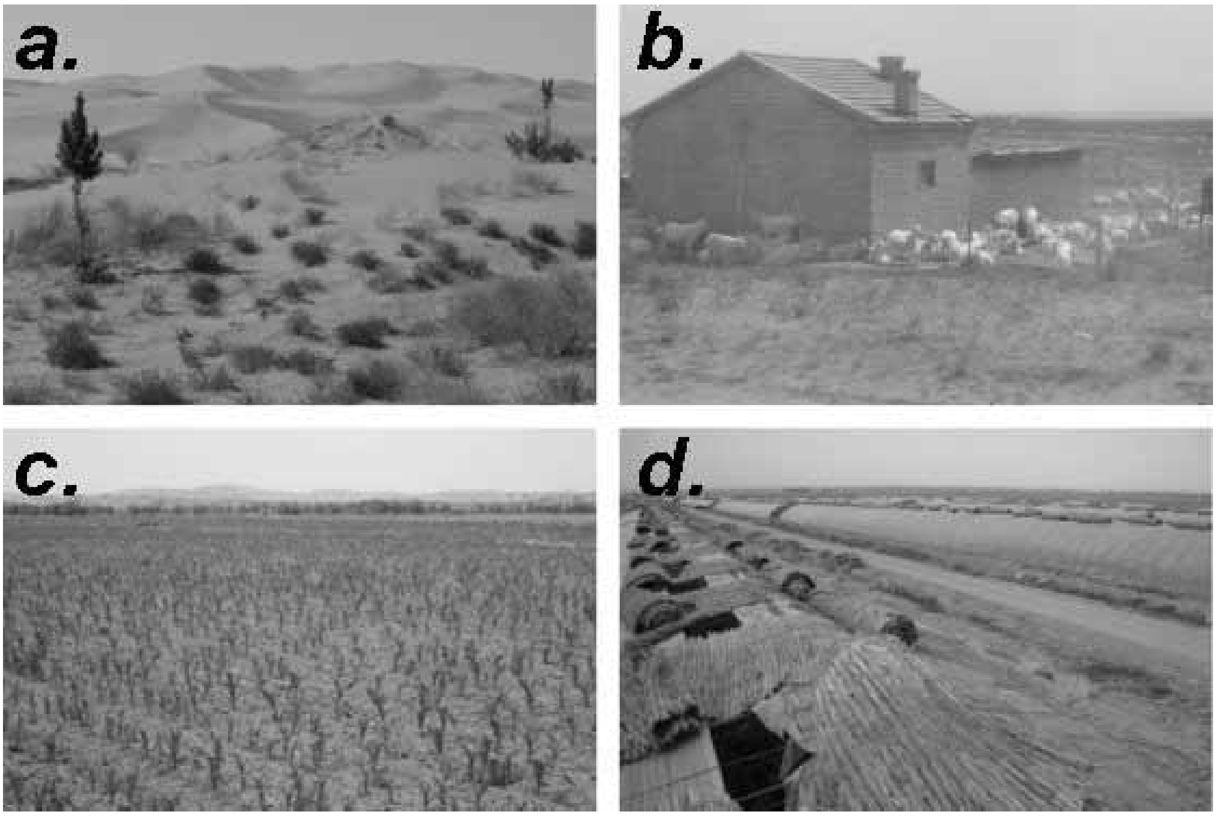


Figure 2.4: Alxa region in Inner Mongolia: a) Landscape of sand dunes and steppe desert along edge of desert, b) Enclosed herd at house, c) Oasis agriculture with shelterbelt woodland, d) Local style greenhouses developed by governments for migrants (Photos: a,b: Werners, May 2007; c,d: Dai, 2007)

[7] In 1993, the Chinese central government launched the "Eight-Seven" Poverty Alleviation Reinforcement Plan, which aimed to solve the poverty problem of 80 million residents in the whole country within 7 years from 1993 to 2000.

[8] Ecological migration (*shengtai yimin* in pinyin Chinese) is a government policy to re-settle herders and farmers living in ecologically fragile and degraded regions to new build or existing communities. Ecological migration in China began in the 1980s in the Southern Ningxia Hui region and continues today in Inner Mongolia and other Western provinces (Du, 2006).

Recent climate policy developments are the recognition of climate change adaptation and mitigation as expressed by the central government's 'Eleventh Five-Year Plan' (NDRC, 2006) and the launch of a national climate change programme in 2007. Although the Alxa development plan makes no reference to changes in temperature, precipitation or severity of extreme weather events (Dai *et al.*, 2008), the regional government has responded to climate change by providing more specified weather forecasts[9] and by subsidising agricultural insurance in two pilot programs (see Section 4.3, 4.4 and 4.9).

At the farm or household level, farmers apply different water-saving techniques and many have experimented with more drought-resistant crops. Other adaptation options that are considered include the introduction of greenhouses, more widespread use of drip-irrigation or no-till cropping, and integration of fruit trees with annual crops in oasis settings in order to reduce denudation, raise water-use and nutrient efficiency, and support economic diversification. The climatic and other challenges associated with farming have led some families to abandon agriculture to find another living in industry or the larger urban centres as a type of livelihood adaptation, resulting in ghost town throughout the region (see Section 4.2 and 4.4). With few exceptions, migrants see the policy of ecological migration as a successful adaptation to what they themselves described as a situation in which vegetation and grasslands had degraded to a point where livelihoods could no longer be sustained (see Section 4.6) (West, 2009).

2.2.3 Enhancing adaptation - constraints and opportunities

The future vulnerability and adaptation of the region will not only depend on the direction and magnitude of expected climate change, but also on the policies to deal with socio-economic and environmental change in the region. The rangeland rehabilitation policies in Inner Mongolia in particular have the potential to create new opportunities as well as constraints. One key challenge is to create balanced and flexible policies that can –if necessary- be altered after evaluation of longer term effects. An example of this challenge is the widely implemented grazing ban. With the recovery of the rangelands, the accumulation of dry material adds to bush fire risk. This suggests that a certain amount of grazing might be necessary to keep dry material levels low while maintaining sufficient plant cover (see Section 4.2). Moreover, while the grazing ban has reduced human induced pressure on the rangelands, it has indirectly increased pressure on the scarce water resources as migrants have been moved to villages located in or beside the few oases remaining in the Alxa region (see Section 4.6). The continuing conversion of oases into settlements and farmland will have major long-term consequences for the regional climate and hydrology, now regulated by oasis ecosystems. Modification of the grazing ban could allow some herdsmen to return to their trade, combining use and protection of grassland (see Section 4.6).

If planned carefully, ecological migration will continue to provide alternative livelihoods for the rural poor as well as release direct pressure on marginal land. While many interviewed migrants

[9] In 2006 Alxa's meteorological bureau initiated a cell phone warning service for 3 Yuan/month (0.30 euro/month). Text message are sent ahead of torrential rain, strong wind, sand storms and heat waves. It has been effective so far as most farmers and herdsmen in Alxa use a cell phone (Dai *et al*, 2008).

express the view that their lives have improved in key areas such as access to healthcare, goods and services, and schooling for their children, challenges remain to ensure that the move is sustainable. These include ensuring adequate and affordable access to clean forms of electricity, providing water for irrigation, drinking and household use, promotion of new cultivation techniques and training to facilitate sustainable transitions from herding to farming. Another challenge is the equity and long-term financial sustainability of existing compensation programmes for ecological migrants. While continuation of compensation programs for rehabilitating grasslands is desirable from the perspective of the beneficiaries -individual herdsmen and farmers- it would arguably require more central government funds than politically feasible (China Council Task Force on Forest and Grasslands, 2001). Beneficiaries will reconsider their activities when the compensation program ends (see Section 4.6).

Illicit economic activities, like the extraction of medicinal plants for local and regional markets have added to landscape degradation. However, cultivation of high-value medicinal plants also creates opportunities for alternative livelihoods and is seen as a promising measure to raise the resilience of the local population and reduce pressure on vulnerable ecosystem. Future policies therefore need to build on successful experiments, such as public-private partnerships in which marketable products obtain additional public funding in exchange for providing environmental services and maintaining social and environmental standards (China Council Task Force on Forest and Grasslands, 2001).

Perhaps the most pervasive constraint to successful adaptation is related to local people's perceptions of the government and its policies. While government policies are important and can provide stimulus and support for successful adaptation at the local level, local people in Inner Mongolia are often ill-informed of the goal of grassland policies that have been conceived, implemented and scaled up rapidly (Runhong, 2001). In addition, there was very little awareness among those interviewed about what they themselves either as individuals or communities could do to adapt to long-term climate and environmental change (West, 2009). This highlights the importance of including the perspective of local people in policies that affect them, and of building local adaptive capacity through environmental education, training and creating space for discussion and sense making (see Section 4.8).

Table 2.4 summarises constraints and opportunities for climate adaptation that were identified in the Inner Mongolia study region.

Table 2.4: Constraints and opportunities for climate adaptation in the Alxa region, Inner Mongolia

	Constraints	Opportunities
Biophysical	Large inter-decadal climate variability. Precarious balance between grassland deterioration, recovery and adding to fire risk	Sand storms trigger national and local attention. Grassland ecosystems are recovering, stabilising the soil and reducing erosion in some areas

	Constraints	Opportunities
Technical	Technical solutions tend to be large-scale and unequal implementation is contested at a local level	Improve irrigation efficiency. Implement sustainable local electricity solutions
Financial	Current government compensation programmes may be financially unsustainable in the long-term	Economic growth provides financial resources to invest in adaptation policies. International willingness to invest in climate policy and research
Institutional	National climate change concerns not reflected in local government policy documents. Inflexible policies and institutions	Stakeholder workshops and forums could help to overcome some of the gaps and engage local decision-makers in formulating and implementing climate policy
Social	Social sustainability of government policies aimed at rangeland rehabilitation	Government policies combine elements of poverty alleviation and economic development, with scope for addressing adaptation
Cognitive and Informational	Little information on climate impacts, the relation to land degradation and policy development is currently available for use by local officials or citizens	People are eager to get more information. Promotion climate and environmental consciousness at the local level through increasing number of bilateral project

2.3 Tisza River Basin

2.3.1 Climate change and impacts on land use and water management

The Tisza River is the largest tributary of the Danube, receiving water from the Carpathian Mountains in Romania, Slovakia and Ukraine. Climate change projections suggest more irregular rainfall and a warmer climate in the Carpathian basin (Láng, 2006; Bartholy *et al.*, 2007), aggravating the three main water-related problems of the Tisza region: floods, in-land water stagnation and droughts (Barta *et al.*, 2000; ADAM Project, 2007b). Between 1998 and 2006 there has been at least one severe flood each year, of a magnitude that was previously associated with the 100-year flood (Timár and Rácz, 2002). Paradoxically, the plains between Danube and Tisza are especially drought prone and Hungarian agriculture and forestry has suffered from extensive droughts in successive years.

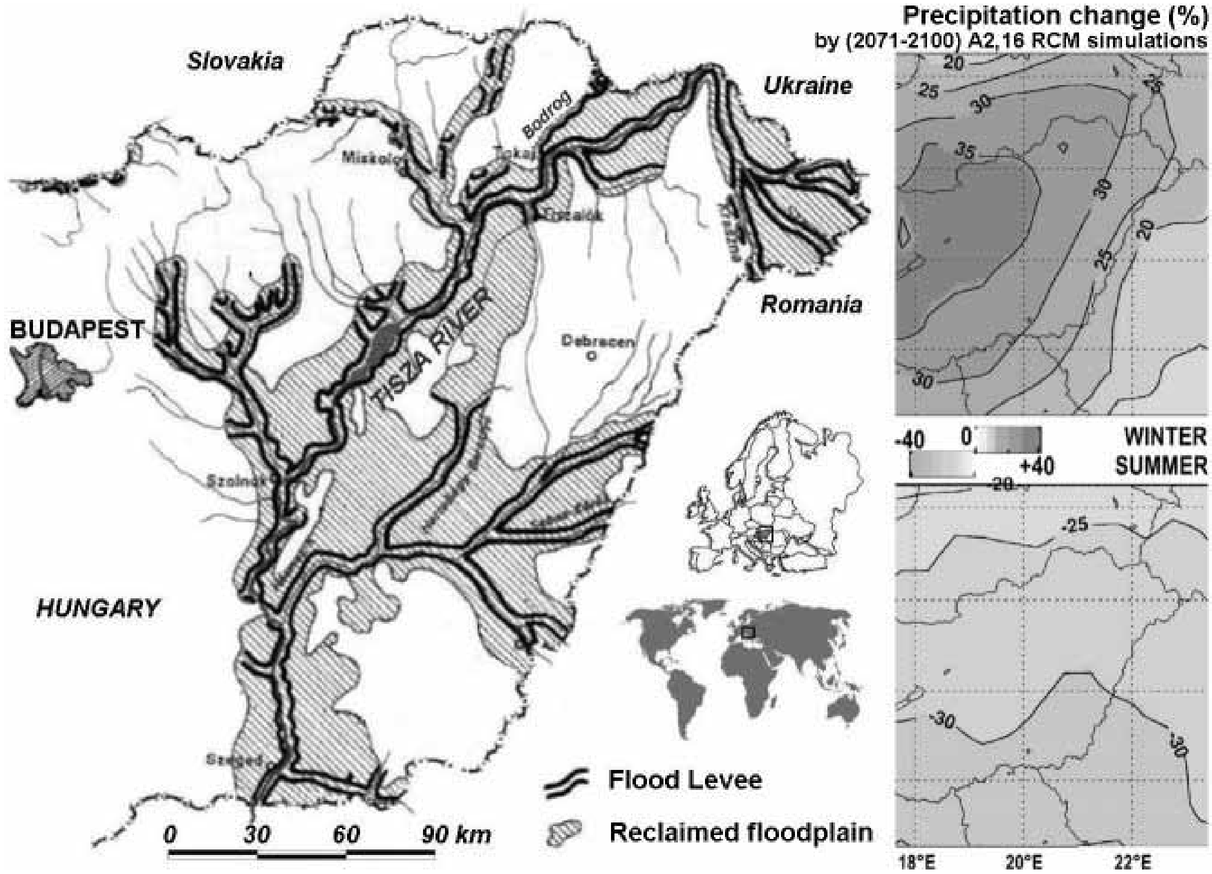


Figure 2.5: Hungarian Tisza River Basin and projected change in average precipitation by 2071-2100 in SRES Scenario A2 using 16 regional climate models (after Szlávik and Ijjas, 2003; Bartholy *et al.*, 2007).

Until the 18th century socio-economic activities in the Tisza valley were predominantly organized around the operation of a system of creeks and channels regulating the water flow between the main river bed and the floodplain (Balogh, 2002). Inundation frequency determined land use. The Tisza floodplain provided a secure income for communities along the river, with a floodplain production system that combined plough land, forest, floodplain orchards, meadows, fish and cattle (Andrásfalvy, 1973; Bellon, 2004). Since then the Tisza River has been heavily modified to cater for large-scale mono-agriculture and river transport. Dikes were built, one third of the river length was regulated and the floodplain was drained, decreasing the total naturally flooded area by over eighty percent. These changes put an end to the traditional water management system and the related production systems (Bellon, 2004).

At present, the main land uses are intensive agriculture (see Section 5.3), wetlands and meadows (the famous Hungarian grasslands or *puszta*). Vulnerability of rural production systems has increased through the loss of local flood and drought resistant crop varieties and processing techniques (Sendzimir *et al.*, 2008). Flood damages are expected to increase under climate change (Koncsos and Balogh, 2007) (see Section 5.7). Socio-economic problems that add to vulnerability include a high unemployment rate, an ageing population, migration and minority issues (Sendzimir *et al.*, 2004; Linnerooth-Bayer *et al.*, 2006). More promisingly, the region has a large undeveloped potential for recreation and nature conservation (Vári *et al.*, 2003; Csete, 2007).

2.3.2 Assessment of adaptation practices

Key drivers of the adaptation discussion in Hungary are climate related extreme events, especially recurring floods and droughts, in combination with national research and institutional change. Three major vehicles for mainstreaming adaptation into land use and water management are: i) the national research project VAHAVA, which led to the National Climate Change Strategy, ii) the new water management plan for the Hungarian Tisza River; and iii) the „SZÖVET" Living Tisza Association with its micro-grant scheme and the promotion of regional markets and products.

The first of these, a research program titled VAHAVA (VAltozas-HAtas-VAlaszadas: change-impact-response) was launched by the Ministry of Environment and Water and the Hungarian Academy of Sciences in 2003 (Láng, 2006). The VAHAVA program aimed to support the development of the national climate policy as well as introducing climate change issues to the public. To this end the program had an explicit outreach strategy. A major outcome of the program was the development of the National Climate Change Strategy approved by the Hungarian parliament in 2008 (www.klima.kvvm.hu). The follow-up project KLIMAKKT pays more attention to the assessment of adaptation options, especially for agriculture (Erdélyi, 2008).

Secondly, reoccurring flooding events and the recent predictions of an increased incidence of floods and droughts (Láng, 2006) have been a driving force behind a new water management plan for the Hungarian Tisza River: the New Vásárhelyi Plan (VTT - www.kvvm.hu/vizeink). Stakeholders value the plan for its participatory approach to integrated land and water management. After initial criticism, regional and national actors collaboratively prepared the implementation plan, with key objectives being to establish improved socio-economic and environmental security through land use and water management (Werners *et al.*, 2009) (see Section 5.8). The key innovation of the plan is the combination of water retention and floodplain rehabilitation as measures to replace or complement prevailing engineering approaches, favouring flood levee construction (Figure 2.6b&c). Albeit behind schedule, the first polders are now under construction. The late realisation of the polder scheme exposes issues relating to the organisation of water management, benefit transfer, financing and land use change continue to be problematic (see Section 5.8). In the Bodrogköz area, where the first retention reservoir of the VTT has been built (Figure 2.6d), stakeholders debate the need for a flexible institutional set-up to manage both extreme floods and droughts by annual shallow flooding of the landscape.

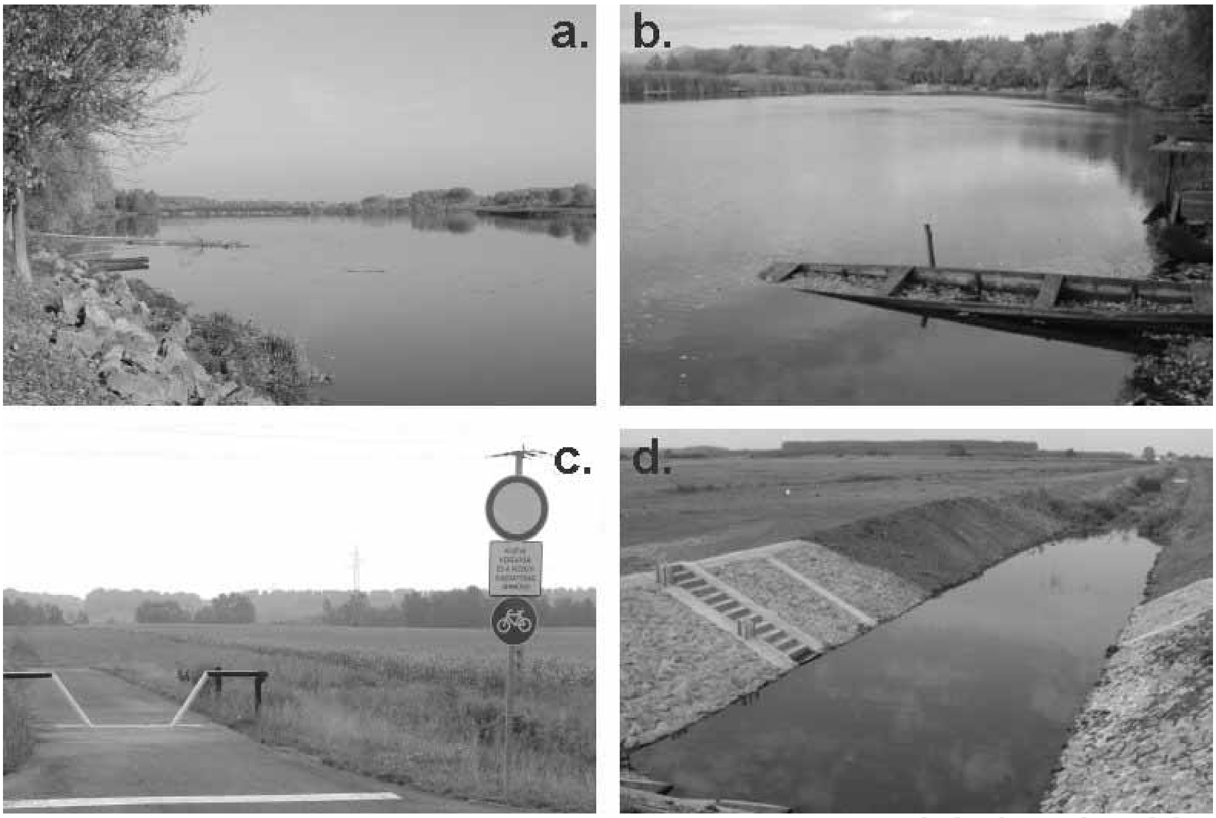


Figure 2.6: Hungarian Tisza River Basin: a) Tisza River at Tiszadada; b) Oxbow lake: traditional water management used oxbows and creeks for water regulation. This inspired the new water management plan; c) Bicycle lane on retention reservoir dike for rural development; and d) Construction of the first retention reservoir. (Photos: Werners, 2007)

Finally, the participation of regional stakeholders in the implementation of the water plan and national climate policies is supported through the UNDP-GEF funded umbrella project 'Living Tisza' (Élő Tisza – SZÖVET project, 2005-2008)[10]. The Living Tisza Alliance[11] aims to harmonize local initiatives in floodplain revitalisation and sustainable rural development. The alliance stimulated the debate on adaptation measures in the region. Its 'Tisza völgy' magazine has facilitated outreach and social involvement, in which local stakeholders emphasised the need to link climate change adaptation, the new water plan and agricultural subsidies in the region. It is intended that raising the income from local floodplain production systems will help to reduce vulnerability of local communities. In 2007 a micro-grant scheme for climate proofing was introduced. Granted projects include facilities for village tourism that aim to reduce climate dependency in agriculture and increase income security (Kajner *et al.*, 2008) (see Section 5.10). Another initiative of the Living Tisza Alliance together with other NGOs is the marketing of regional products though the introduction of 'Élő Tisza' eco-label and online retail that can help producers to change production as a response to climate change.

[10] http://waterwiki.net/index.php/Conservation_and_Restoration_of_the_Global_Significant_Biodiversity_of_the_Tisza_River_Floodplain_through_Integrated_Floodplain_Management
[11] www.elotisza.hu

2.3.3 Enhancing adaptation - constraints and opportunities

While the VAHAVA project initiated a national debate on climate adaptation, many issues remain unresolved. These include the harmonization with other policies, a coherent and financially robust adaptation program and the clarification of the role of different actors and agencies. Regional public local action groups and NGO initiatives (like the Living Tisza Alliance) can carry the adaptation debate forward.

The implementation of the new water management plan holds many lessons for mainstreaming adaptation. At present, water infrastructure is in the planning stage, with the first retention area constructed. However, measures that focus on social adaptation, like rural development and support of floodplain production systems (e.g. extensive fishing, utilizing biomass of water related areas, floodplain orchards) are subject to significant delays. The causes for the delays were discussed in a series of interviews and workshops (Werners *et al.*, 2007a) (see Section 5.8). Direct obstacles to implementation were said to be the required land acquisition and authorisation for the measures. Institutional fragmentation of responsibilities and the lack of strong management were considered a barrier, resulting in a comparatively low ranking of floodplain revitalisation and rural development measures in national development priorities and the related budget allocation. Other complexities were also cited, with EU accession and the accelerated implementation of European directives and legislation heightening the complexity of organisational responsibilities and financial flows. For example, EU accession offers access to new funds as well as spurring the Hungarian government to cut budgets in order to reduce overall budget deficits. At the same time, EU standards and practices for agriculture and water management offer an opportunity to make existing governance and planning practices more effective, participatory and sustainable (Commission of the European Communities, 2001).

Actors in the Tisza region are keen for a clarification of the roles of different parties involved in the new water management plan and expressed a strong interest in establishing a multi-stakeholder implementing agency with national government and other stakeholder representatives. In addition to formal coordination, actors identified options to strengthen informal relations and cooperation between non-governmental agencies (Matczak *et al.*, 2008). This includes awareness raising about -amongst others- the impacts of climate change and the associated flood and drought risks see Section 5.3). Actors also stressed the importance of local and regional markets and public-private sector initiatives. For example, by encouraging local investment in flood protection and floodplain rehabilitation, and collaborating with actors in downstream urban areas to support the development of water retention .

Given the shortage of financial resources, actors suggested integrating adaptation, the new water plan and the Hungarian regional development programs. The costs and benefits of adaptation and floodplain management have to be shared between many parties at different scales. A re-evaluation of resource allocation is suggested, including i) support for sustainable agriculture and land-use management (see Section 5.10), ii) subsidies for renewable energy, levelling the price difference between renewable energy & average energy price, iii) agro environmental schemes and removing damaging current subsidies like compensation schemes for farmers in areas at risk of inundation, iv) property rights including common interest associated with community lands (see Section 5.9), and v) regulation of the use of EU funds in several sectors of the Hungarian economy (e.g. CAP, EU cohesion funds and Natura2000). Insurance is only developing at a slow rate as actors expect state support for emergency situations as and when they arise (Vári *et al.*, 2003).

Socio-economic constraints for adaptation in the Tisza Valley are the economic vulnerability of local production systems, social problems such as poverty, migration, segregation of minorities (gipsy minority), old infrastructure and inequalities within the educational system. The level of education is low, both in general and in vocational training, contributing to high unemployment rate and high social vulnerability (cf. Fekete, 2006). The initiatives of the Tisza Alliance show that the informal networks and local production systems have degraded, but are capable of recovery. Small-scale bio-energy schemes and regional markets are promising new developments that will have to prove themselves sustainable in the future (see Section 5.10). Traditional land use systems hold lessons for the future, or as one actor put it 'stay where the old village used to be'. Table 2.5 summarises constraints and opportunities for climate adaptation that were identified in the Tisza region study region.

Table 2.5: Constraints and opportunities for climate adaptation in the Tisza River Basin

	Constraints	Opportunities
Biophysical	Floods are infrequent and alternate with droughts, shifting policy attention	Using floodplains for water retention restores ecosystem services. Extreme events trigger awareness
Technical	Old infrastructure	Water retention
Financial	Severe budget constraints. High dependency on European funds. Low priority for sectoral ministries.	European and international funds support regional coalition. Micro-grant scheme. Re-evaluation of resource allocation
Institutional	Harmonization with other policies poor. Fragmented responsibilities. Property rights rigid and ill-defined	Regional coalition negotiating regional solutions and policy change. Adaptation can be integrated in ongoing discourse on water policy.
Social	Allocation of retention areas problematic. Dominant land use not conducive to water retention	Promotion of more climate proof local products. Learning from traditional land use and water management
Cognitive and Informational	Adaptation options are contested. Limited access to socio-economic and climate data	Recognition of the limits of prevailing flood levee dominated water management. Regional coalition debating climate impacts and adaptation options

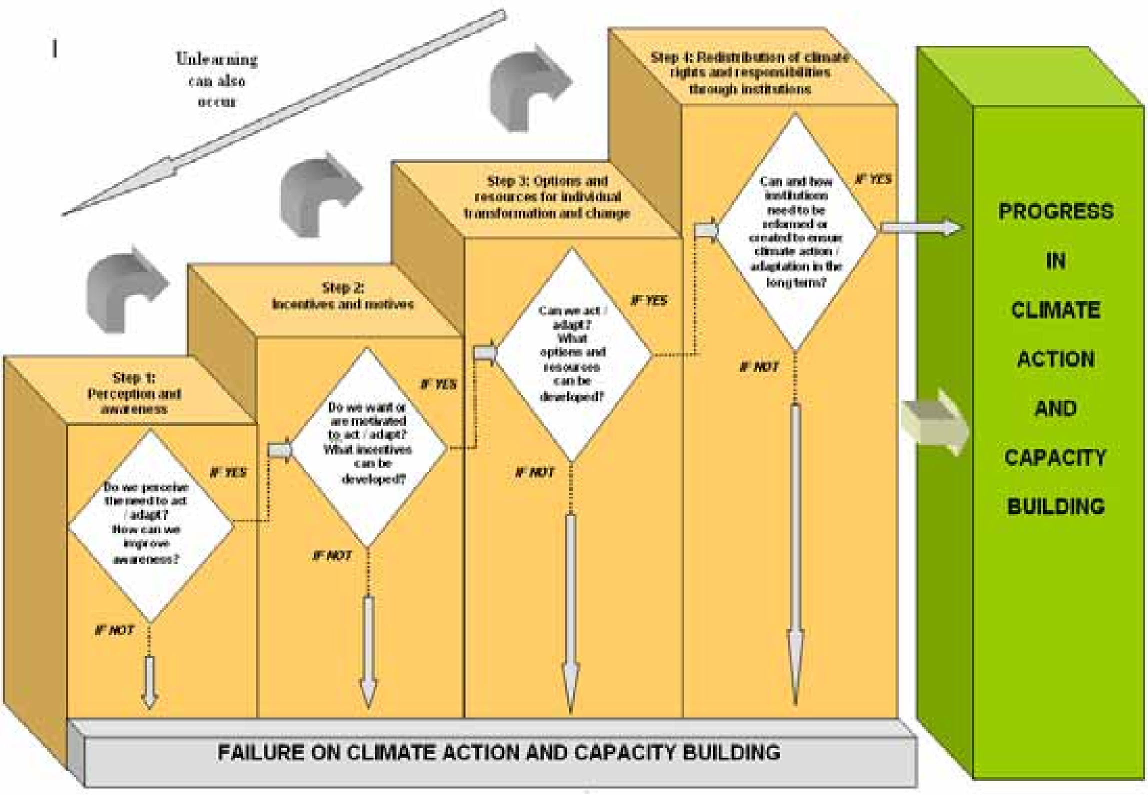
3 Guadiana River Basin background studies

3.1 Conclusions final workshop

The final Guadiana stakeholder workshop took place at the University Pablo Olavide of Seville on the 6 February 2009. It was attended by the 18 stakeholders ranging from policy making agencies, academia and interests groups such as irrigation organisations together with 7 researchers from the ADAM project.

The workshop was structured into three main sessions. First, in the morning, the invited stakeholders gave some presentations. These were mainly from policy makers working on adaptation strategies both at the level of the autonomous Community of Andalusia, within the sector of agriculture, and also from a representative of the Guadiana river basin authority. Then in the second morning session, the ADAM team presented some of their results, such as those provided by DISAT on agriculture in the Guadiana (see Section 3.2) and those on tourism by ICIS (see Section 3.4). Discussion emerged as a result of those presentations. Finally, the afternoon session was devoted to testing the participatory approach of the 'Climate Learning Ladder' (see Box). The meeting ended by a presentation by IEST on the concept and approach of 'Integrated Climate Governance' and its implications for the Guadiana and the Autonomous Community of Andalusia (as they were our hosts) (see Section 3.5 and 6.2). In the following lines we concentrated in commenting the use of the climate ladder during the workshop.

Box: The climate learning ladder



The development of long-term capacities to deal with climate change requires of methods capable to address in an integrated way broader social and political issues that go beyond the simple representation of impacts. In particular, new climate tools and procedures need to address from a context-based perspective, how public awareness can be improved, what incentives can be developed and what real options exist for individual transformation and institutional innovation.

During the afternoon session a simple dialogic tool was presented to explore the different dimensions which analytically have been selected as critical to build adaptation capacities. This tool, the 'climate ladder', is based on the assumption that building enduring integrated climate governance capacities can be understood as a broad social learning process –that goes beyond simply having 'more knowledge' either scientific or popular- consisting of a series of steps. In particular, dealing both in a coherent and comprehensive manner with climate adaptation and mitigation depends on whether relevant agents are: 1. Aware of the risks and opportunities posed by climate change, 2. Sufficiently motivated to take action 3. Develop enough individual capacities for transformation, collaboration and change, and 4. Are able to develop the necessary institutions to distribute the attendant responsibilities and sustain action in the long term. Failing to complete any one of these steps means failing to achieve the desired common good results. Unlearning can also occur whenever gains in the knowledge or abilities which allowed agents to move up this hypothetical ladder are lost.

To apply the climate learning ladder, first, participants were explained the concept and content of the 'climate ladder' and were asked to systematically address two key questions for each step, one related to the analysis of the situation about perceptions, motives, individual capacities or institutions and the others on how each of this dimensions could be improved and by what measures. Two groups were formed: one focusing on competences and actions taken by the policy making agencies at the Andalusian regional government and the other looking at the transboundary cooperation and development agencies within the Guadiana river basin. Second, participants were asked a series of structured questions based on the following headings:

- to what extent climate risks and opportunities are perceived by local agents and how awareness on climate change can be improved?,
- Which type of incentives can be developed to support ICG?,
- What type of options for individual transformations and action are available to deal with climate change?, and
- How and which type of institutions can be developed to ensure that climate rights and responsibilities are properly delivered in the long term?.

And third, for each of the four steps of the ladders participants were asked to provide some insights on potential policy measures that could be implemented to help to improve either climate awareness, incentives for action, option development and institutional reform, hence moving 'up' the ladder.

Our results show the climate ladder tool works effectively to communicate complex issues regarding climate change issues among different stakeholders and that progress in learning and building integrated climate governance capacities cannot be done by working at one single level, scale, or policy domain but interaction of parties with different interests, responsibilities and knowledge is needed. Moreover, people feel more comfortable and are able to suggest a greater number of measures and insights regarding steps 1 and 2.

Figure 3.1: Using the climate ladder to support deliberation on climate strategies. ADAM Guadiana workshop, Seville 6 February 2009.

3.2 Impacts and adaptation for agriculture

Marco Moriondo, Giacomo Trombi, Marco Bindi

3.2.1 Introduction

In this background study, we evaluated climate impacts on the main crops and the effect of adaptation measures in agriculture in the Guadiana River Basin (GRB). We considered six adaptation measures, plus the "no adaptation" one: use of cultivars with longer (1) and shorter (2) growth cycles, increased fertilizer application (3), application of irrigation water to rain-fed crops (4), and shifting the sowing date forward (5) or backward (6). Based on our result in the soping phase of the regional case studies, discussions in the region and literature review (e.g. Eitzinger et al. 2008), measures were selected with respect to both economic and technical feasibility. In particular, measures that do not require significant investments (neither from farmers nor from governments) were preferred, with the exceptions of irrigation. No significant progresses in terms of available technologies, such as more efficient irrigation systems, were considered in this study. Both winter and summer grown crops were simulated, with particular attention to the latter, since the most severe climate conditions in GRB are projected to occur during the hot season.

The results of a General Circulation Model (GCM) empirical downscaling for current climate (1975-2005) and a future period (2000-2099) corresponding to an average increase of 2°C (A2, SRES scenarios), were used to feed a crop model (CropSYST) in order to quantify the impact of temperature and rainfall changes on agriculture considering also changes in the frequency of extreme events (heat waves and drought). The same climatic dataset was used to compare the performances of different adaptation measures in a warmer climate. Due to the coarse GCM resolution, firstly an empirical downscaling procedure was carried out in order to reproduce, on a scale suitable for impact assessment, the future climate over the GRB. This procedure, based on the use of a weather simulator (LARS WG, Semenov and Barrow, 1997), allowed considering both change in mean climate as well as changes in the climate variability. The results of this procedure were used to feed the crop growth simulation model.

3.2.2 Materials and methods

3.2.2.1 Climate data

Due to the coarse GCM resolution, an empirical downscaling procedure was carried out in order to reproduce the future climate of GRB at a regional scale, which is more suitable for impact assessment in agriculture (i.e. 50km X 50km). The procedure was based on the use of a weather simulator (LARS WG, Semenov and Barrow, 1997), which allowed changes in mean climate as well as in climate variability, as derived from the GCM, to be included for the studied time span. According to the result of Giannakoupolos et al. (2005) the period 2030-2060 as simulated by HADCM3 in A2 scenario (Pope et al., 2000), was selected to represent a +2°C scenario.

Dynamical downscaling models, such as Regional Circulation Models, RCMs, allow the same spatial resolution to be achieved, however, with the proposed procedure some limitation inherent to the use of these datasets may be overcome. Firstly, observed data are used to generate the baseline period, so to reduce possible bias errors in simulating the present climate as in RCMs (Moberg and Jones, 2006). Additionally, this procedure allows the generation of climate data for different time slices, whereas RCMs are limited to the 2070-2100 period. Finally, the length of each climatic dataset is not limited to 30 years, as in RCMs, but may be extended as necessary by using the stochastic data generator. In particular, two periods from the results of HADCM3 GCM, 1975-2005 and 2030-2060 respectively, were statistically downscaled to reproduce, on regional scale, the future climate corresponding to a 2°C above pre-industrial level. This GCM consists of an atmospheric GCM coupled to an ocean GCM. The atmospheric component of HadCM3 has 19 levels with a horizontal resolution of 2.5° of latitude by 3.75° of longitude, and produces a global grid of 96 x 73 grid cells.

According to LARS WG procedure for downscaling (Semenov and Barrow, 1997), available observed daily weather data for a given site were used to identify a set of parameters for probability distributions of weather variables as well as correlations between them (calibration stage). These parameters were then used to generate the synthetic weather time series describing the present period, which were subsequently used as baseline to be perturbed using forcing factors derived from the GCM.

In this work the observed daily data of 2248 grid points (Tmin, Tmax, rainfall and radiation) for the period 1975-2005, spaced 50 x 50 km over the EU domain (data from MARS project

http://mars.jrc.ec.europa.eu/) were used for the local calibration of the stochastic weather generator. After calibration, 100 years of synthetic daily weather data were produced for each one of the 2248 grid points to represent the baseline period over the domain. The results of HadCM3 GCM for A2 scenario (2030-2060 time span) were used to derive the forcing factors to be used in the downscaling procedure. These were computed for each of the 304 GCM grid points over the domain, as monthly average differences of Tmin, Tmax, rainfall and radiation between the future and the reference period (1975-2005). The relative change in both standard deviation of temperatures and rainfall, and in duration of wet and dry spell were also calculated.
Finally, forcing factors calculated for each GCM grid were applied in the downscaling procedure to perturb the relevant climatology of the observed dataset generating stochastically 100 years of daily data for each 50x50 km grid point. The results of the statistical downscaling procedure related to 28 grid points over the GRB were chosen to feed the CropSYST growth model simulation for present and future periods.

3.2.2.2 The CropSYST crop growth model

CropSYST is a multi-year, multi-crop, daily time step crop growth simulation model (Stockle et al, 2003). It simulates the soil water budget, soil-plant nitrogen budget, crop canopy and root growth, phenology, dry matter production, yield, residue production and decomposition, and erosion. The model allows the user to specify management parameters such as sowing date, cultivar genetic coefficients (photoperiodic sensitivity, duration of grain filling, maximum LAI, etc.), soil profile properties (soil texture, thickness), fertilizer and irrigation management, tillage, atmospheric CO_2 concentration etc.
The water budget in the model includes precipitation, irrigation, runoff, interception, water infiltration, water redistribution in the soil profile, deep percolation, crop transpiration, and evaporation. Potential evapotranspiration may be estimated by using wither the Penman-Monteith or the Priestley-Taylor method. Crop evapotranspiration is determined from a crop coefficient at full canopy and ground coverage calculated by canopy leaf area index. Water dynamics in the soil is handled by either a simple cascading approach or Richards' equation, the latter solved numerically using the finite difference technique. The nitrogen budget includes soil N transformations (mineralization, nitrification, denitrification, volatilization), ammonium sorption, symbiotic N fixation, crop N demand and crop N uptake. The water and nitrogen budgets interact to produce a simulation of N transport within the soil. Chemical budgets (pesticides, salinity) are also kept and interact with the water balance. Crop growth is simulated for the whole canopy by calculating unstressed biomass growth based on potential transpiration and on crop intercepted photosynthetically active radiation. This daily potential growth, expressed as biomass increase per unit area, is corrected by four limiting factors: light, temperature, water, and Nitrogen. Crop production is determined according to the harvest index (HI = harvestable yield/aboveground biomass) and translocation factor. Root depth is simulated as a function of leaf area development, and reaches its maximum when the plant is flowering. The duration of phenological phases is calculated according to heat units, eventually modulated by photoperiod and vernalisation. The thermal time may be accelerated by water stress. The most important model inputs are: daily weather data, properties and initial conditions of soil profile (soil texture, thickness, field capacity, wilting point, bulk density, crop residues, water content,

mineral nitrogen and organic matter), cultivar genetic coefficients (photoperiodic sensitivity, duration of grain filling, maximum LAI, etc.), dates and amounts of products applied for each fertilization and irrigation event, sowing date, tillage operations and residue management. Main daily model outputs are above- ground biomass (AGB), leaf area index (LAI), root depth, potential and actual evapotranspiration, soil water and nitrogen balance.

Additionally, both the impact of drought stresses and heat waves (as in Moriondo et al., 2009) occurring either at anthesis or during grain filling, were simulated.

The simulation of crop development in CropSYST is mainly temperature-dependent and it is based on the thermal time required to reach each specific phenological phase. Thermal time is calculated as growing degree-day (GDD, °C day^{-1}) defined as the sum of differences between the average of the daily maximum and minimum temperatures, and a base temperature, usually 10 °C, accumulated throughout the growing season (starting from sowing until harvest). Only average air temperatures above a certain threshold and below a cut-off temperature are considered in the calculation.

The core of the model is the calculation of the biomass potential growth under optimal conditions (without water nor nitrogen stresses) based both on crop potential transpiration and crop intercepted photosynthetic active radiation. The potential growth is then corrected by possible water and nitrogen limitations, and the actual daily biomass gain is calculated. The simulated yield is finally obtained as product of the actual total biomass cumulated at physiological maturity and the Harvest Index (HI = harvestable yield/above-ground biomass).

Furthermore, the use of a modified version of the model allowed considering the effect of increasing atmospheric CO_2 concentration on potential evapotranspiration, crop water use efficiency (WUE, [Kg m^{-3}]) and radiation use efficiency (RUE, g MJ^{-1}) (Tubiello et al. [2000]).

In CropSYST, drought stresses occurring at anthesis and grain filling period are already considered as yield-reducing factors. A mean water stress index (ranging from 0 [no stress] to 1 [maximum stress]) is calculated during these phases and used to proportionally decrease the HI.

On the contrary, CropSYST, like other widely used models, does not include the simulation of heat stress on final yield. This results in a potential underestimation of climate change impact in agriculture (Porter and Gawith, 1999) since heat stresses at anthesis have been widely demonstrated to be a yield reducing factor (Challinor et al. 2005).

In this work, heat stress impact on final yield was included into CropSYST model results using the approach proposed by Moriondo et al. (2009). This model is based on the simulation of final HI as function of the Grain Filling duration (GF, expressed as the number of days from fruit-set to maturation) and the daily increase of HI (dHI/dt, assumed to be constant during the whole GF [Bindi et al., 1999]). Accordingly:

$$HI = \frac{dHI}{dt} \times GF$$

The approach proposed by Challinor et al (2005) and adapted to CropSYST by Moriondo et al. (2009), was therefore used to calculate the impact of heat stress events on dHI/dt during anthesis. Such episodes were identified by comparing the Tmax to a critical value Tcrmin, above which grain-set starts to be reduced up to the minimum level corresponding to a severe heat shock (Tlim, the temperature at 0% grain-set). For both winter and summer crops heat waves during pre- and post-anthesis were demonstrated to decrease grain-set (Porter and Gawit, 1999;

Chimenti and Hall, 2001). Accordingly, a thirteen-days span, from –5 to +8 days from full anthesis date, was assumed as sensitive to the effect of heat stress (Tashiro and Wardlaw, 1990) with Tcr=31°C and Tlim=40°C at full anthesis (Narciso et al., 1992). The heat stress impact on dHI/dt was then calculated and used to obtain HI, which is the product of dHIa/dt and GF, to be subsequently decreased by the effect of drought stress as calculated by CropSYST. Yield was then recalculated as the product of the resulting HI and the total above ground biomass (AGB) as simulated by CropSYST. According to this approach, both heat and water stress models were used to calculate final HI in present and future scenarios, and this was combined to the total cumulated biomass as simulated by CropSYST. Finally, atmospheric CO2 concentration was set to 350 ppm in the present scenario, and then it was simulated to be increasing progressively during the hundred years up to around 800 ppm.

3.2.2.3 The simulated crops

Both winter and summer crops were considered in this work. Durum (*Triticum turgidum* L. subsp. *durum*, including vernalization process, winter wheat) was selected as winter crop, whereas soft wheat (not including vernalization process), maize, soybean and sunflower represented the summer crops. CropSYST model was first calibrated for the present scenario to faithfully reproduce yield of considered crops on a regional scale as obtained by EUROSTAT for the last 10 years. To ensure a likely simulation of the water balance at grid point scale, the specific soil properties (thickness and texture) relevant to each grid point were extracted from the European soil database Eusoils (spaced 10 x 10 km). The soil class having the higher frequency within each 50x50 grid point grid was considered as representative of the whole grid point.

3.2.2.4 Adaptation measures

The study included 6 agricultural adaptation measures for GRB, which are respectively: (i) and (ii) shifts in the sowing date, (iii) application of irrigation water to rain-fed crops, (iv) increased fertilizer application, and (v) and (vi) use of cultivars with both longer and shorter growth cycles.
The "Future with No-Adaptation" (FNA) option, as well as the present scenario simulation, included optimal nitrogen fertilization (150 kg ha^{-1} split 50% at sowing and 50% at anthesis stage) and no irrigation (with the exception of maize). Tillage (20 cm depth) was set 10 days before the sowing date: in late summer for winter crops and in early spring for summer crops. Sowing date was calculated by the model starting from a predetermined day (20^{th} November for winter crops, 1^{st} March for summer ones): once the specific thermal requirements of the simulated crop had been met, model simulated the sowing.

In order to simulate the adaptation measures to be studied, CropSYST was set up as following:

- **Shorter Cycle Cultivars** (SC): each growth cycle phase was simulated to be 20% shorter (in days) than in FNA;
- **Longer Cycle Cultivars** (LC): plant cycle was set to be 20% longer;
- **Increased Fertilization** (IF): 180 kg N ha^{-1} (+20% respect to FNA) split 50% at sowing and 50% at anthesis stage;
- **Irrigation** (I): water available content was set not to be below 40% of the field capacity (automatic irrigation was activated below that threshold); for maize this adaptation measures

is equivalent to FNA;

- Early Sowing (ES): the sowing date was anticipated by 15 days respect to FNA;
- Late Sowing (LS): crop was sown 15 days later than in FNA simulations.

In order to have the impact of climate change quantified, land use data (arable land layer from Corine 2000) were overlaid to the interpolated map of yields in GRB.

3.2.3 Results

3.2.3.1 Climate data validation

The effectiveness of LARS WG in reproducing present climate was tested by carrying out a statistical comparison of the weather generator outputs with the observed data over a sample of 100 grid points randomly selected across the domain. A statistical comparison of synthetic weather data generated using LARS-WG with the parameters derived from observed weather data was then carried out.

Generated and observed mean monthly temperatures and rainfall were compared to provide a general overview of LARS WG performances on the mean local climate generation. Additionally, the quarterly probability distributions for length of wet and dry series, frost (days with minimum temperature less than 0), and hot series (days with maximum temperature greater than 30) and the monthly probability distributions for precipitation were compared to test LARS WG reliability in simulating climate variability. The probability distributions for the generated and observed data were compared using the chi-square goodness of fit test. The means were compared using the t-test. In each case a p-value was calculated, which is used to accept or reject the hypotheses that the two sets of data belong to the same distribution.

The results of the statistical analysis indicated a general overall agreement between observed and simulated data both in terms of mean values and climate variability. Minimum and maximum mean monthly temperatures and their relevant variability were well reproduced by LARS WG, especially in autumn-winter (errors within 5% of test cases), whilst the errors slightly increased in spring summer (up to 8% of test cases). The quarterly probability distribution of frost spell was also well represented by LARS WG in the test cases, with errors ranging from 15% in winter to 12% in autumn. The simulations of hot spell showed an overall error of 13%. The mean monthly rainfall showed limited errors (up to 4% of the test cases) mainly in winter autumn and also monthly probability distributions were well simulated with errors included between 2% and 8%. Dry and wet spell were well simulated in all the seasons, even though in summer the overall error reached 14% and 16% of test cases, respectively.

3.2.3.2 Crop model calibration and validation

CropSYST model was calibrated to reproduce yield of winter and soft wheat, maize, sunflower and soybean on GRB. In particular, the calibration was performed using the output of LARS WG procedure as obtained for the present scenario as input for CropSYST. In the first iteration of the calibration process, the average crop yield calculated for a 30 years long time span for each of the 28 grid points were aggregated at NUT1 level and compared to the relevant yield averaged for the period 1995-2007 using correlation coefficient (r) and the root mean square error (RMSE) as goodness-of-fit indicators. Secondly, both WUE and RUE default values were iteratively tuned, so to match the range of values reported in literature for each crop, in order to maximize the goodness-of-fit indicators relevant to each crop.

For instance, while for soybean and sunflower the WUE and RUE default specific parameters in CropSYST provided the best results in terms of both r (0.7 and 0.85 for soybean and sunflower respectively, significant for $P<0.01$) and RMSE (0.59 and 1.25 Mg ha^{-1}), for spring and winter wheat only r resulted highly significant ($P<0.01$; 0.78 and 0.77 for winter and soft wheat respectively) whereas crop yield was highly underestimated causing a RMSE of 1.3 Mg and 1.7 Mg ha^{-1} respectively. The calibration process resulted in a significant improvement in the correspondence between simulated and observed data, with a BTC=5.5 Kg m^{-3} and RUE=3.2 g MJ^{-1} for winter wheat and to BTC= 6.8 Kg m^{-3} and RUE =3.2 g MJ^{-1} for spring wheat, and an r ranging from 0.8 (winter wheat) to 0.82 (soft) with a relevant RMSE of 0.9 and 1.1 Mg ha^{-1}.

3.2.3.3 Crop simulations

According to our study, based on the analysis of the impact of climate change on several crops, both spring-summer and winter ones, in the GRB, there are different suitable strategies to cope with the projected climate. It must be noticed that our results and conclusions are strictly related to agricultural sector, with absolutely no regards to economical aspects, such as market trends and cost of inputs, institutional framework, as new incentives and subsidies, special laws for agriculture and climate change; however, since these results are expressed as relative change in yield respect to present period values, they may be adapted to feed other models, such as economic ones.

Possible new options related to new technologies have been taken into account by simulating the two cultivars, one with shorter, the other with longer vegetation cycle, as possible results of selection and research on crop varieties.

In general, winter crops will suffer less climate change impacts, in comparison to summer ones. Seasonal changes, in fact, will be more severe in future summers, both in terms of increases in temperature, climate variability, extreme events frequency, and precipitation intensity, and in terms of changes in rainfall patterns. Table 1 shows the average water needs of the crops in GRB as simulated in future period (2000-2099). Table 2 shows the average yields relative change of crops as simulated for the whole GRB in future period (2000-2099) with respect to present values (1975-2005).

Table 3.1 - Irrigation: water needs (m^3 ha^{-1}) in future period (2000–2099)

	Adaptation Measure					
	FNA	SC	LC	I	ES	LS
Corn	2093	1485	2712	-	2046	2097
Soybean	-	-	-	792	-	-
Spring Wheat	-	-	-	1446	-	-
Winter Wheat	-	-	-	975	-	-
Sunflower	-	-	-	1723	-	-

Table 3.2 – Yields: GRB average yields relative change in future period (2000-2099) respect to present (1975-2005)

	Adaptation Measure						
	FNA	SC	LC	IF	I	ES	LS
Winter Wheat	-0.52%	-9.53%	3.25%	-0.37%	5.67%	-2.02%	-0.20%
Spring Wheat	-2.46%	-2.40%	-10.23%	-2.48%	6.64%	-5.24%	-0.86%
Soybean	-15.60%	2.98%	-32.03%	-15.70%	-10.58%	-13.45%	-19.30%
Maize	-36.16%	-24.04%	-46.88%	-45.24%	-36.17%	-29.60%	-42.76%
Sunflower	-6.04%	11.40%	-22.53%	-6.00%	14.53%	-2.97%	-11.53%

Winter crops.

The **winter wheat** will not particularly suffer significant decrease in yield due to climate change: FNA option showed no yield losses, besides a small decrease in a limited portion of eastern coastal zone. One adaptation measure, however, that is irrigation (I), resulted in an increased production in the central and north-eastern zones (+9 to +15%, +5.6% in average over the whole basin), while the rest of the basin was not affected. The other adaptation measures considered did not affect significantly the final yield, even if a slight decrease has been simulated in the abovementioned coastal area; finally, cultivars with shorter growth cycle (SC) decreased the production over almost the whole basin, since in the simulations the plants had less time to accumulate nutrients, while not having particular benefits that could occur if skipping critical periods, in terms of extreme events as for soybean below.

Spring-summer crops.

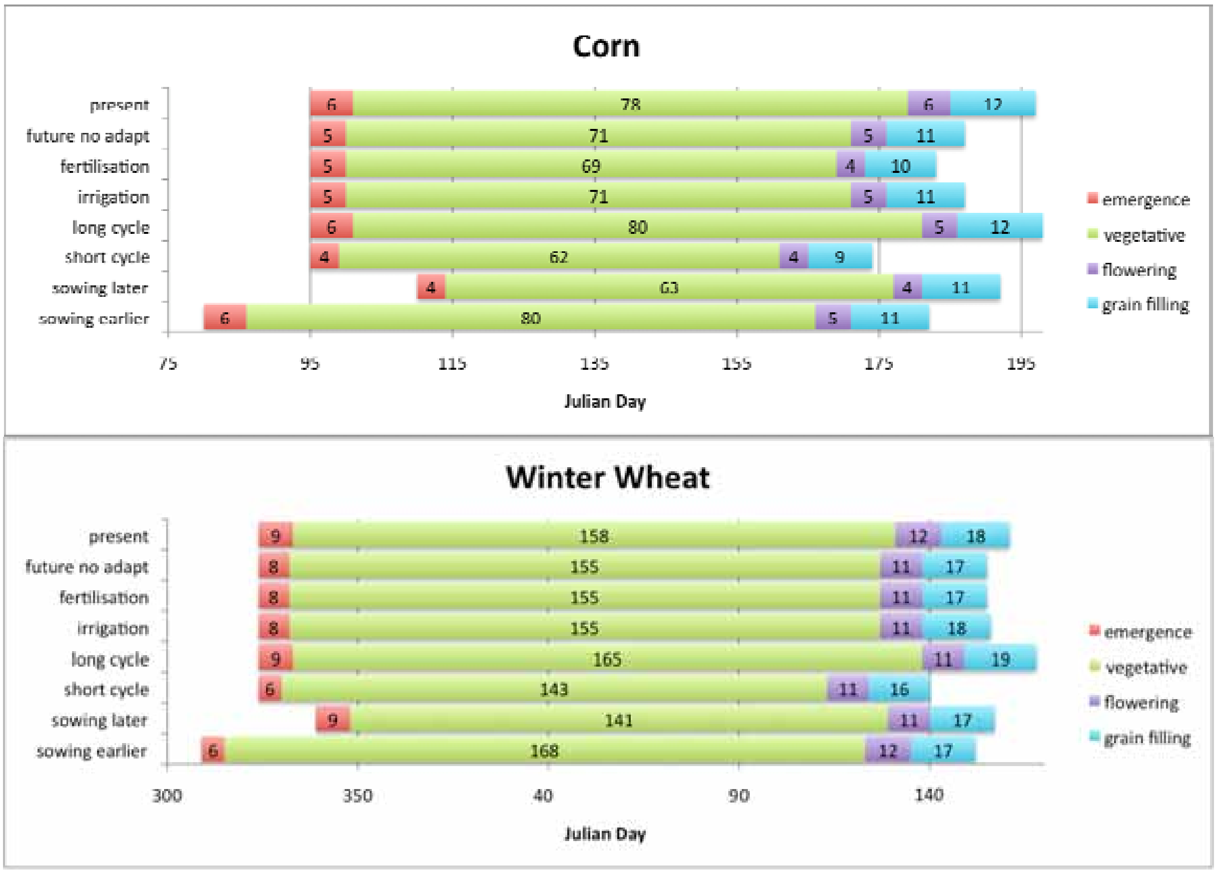
Sunflower: this crop had its yield decreased by the effects of climate change, when no adaptation measures were implemented (FNA), in almost the whole northern zone of the basin (-5% to -22%, -6% as basin average). Among the simulated measures, changes in sowing date, both earlier and delayed (ES and LS), were found to reduce the final yield (in the central-northern area by about -8% to -20%, with a basin average of -2.9% the former; in almost all the basin the latter, minimum of -28%, -11.5% in average); fertilization (IF) had negative effects, being the production reduced in the northern area by around the -10% (-6% over the whole basin). The use of longer vegetative cycle cultivars (LC) resulted in severe decrease of final yield in the whole basin (-22.5%), while the SC showed a slight increase (+11.4% in average) in the production, especially in the eastern-northern area (up to +28%) and in the south of the basin (around +13%); the shorter cycle, in fact, let the plant mature before extreme events, such as droughts and heat waves, occur. Finally, irrigation (I) resulted in an increase of the yield in the southern and eastern-northern part of the basin, with values ranging from +10% up to +50% (+14.5% as basin average), helping plants during the drought periods.

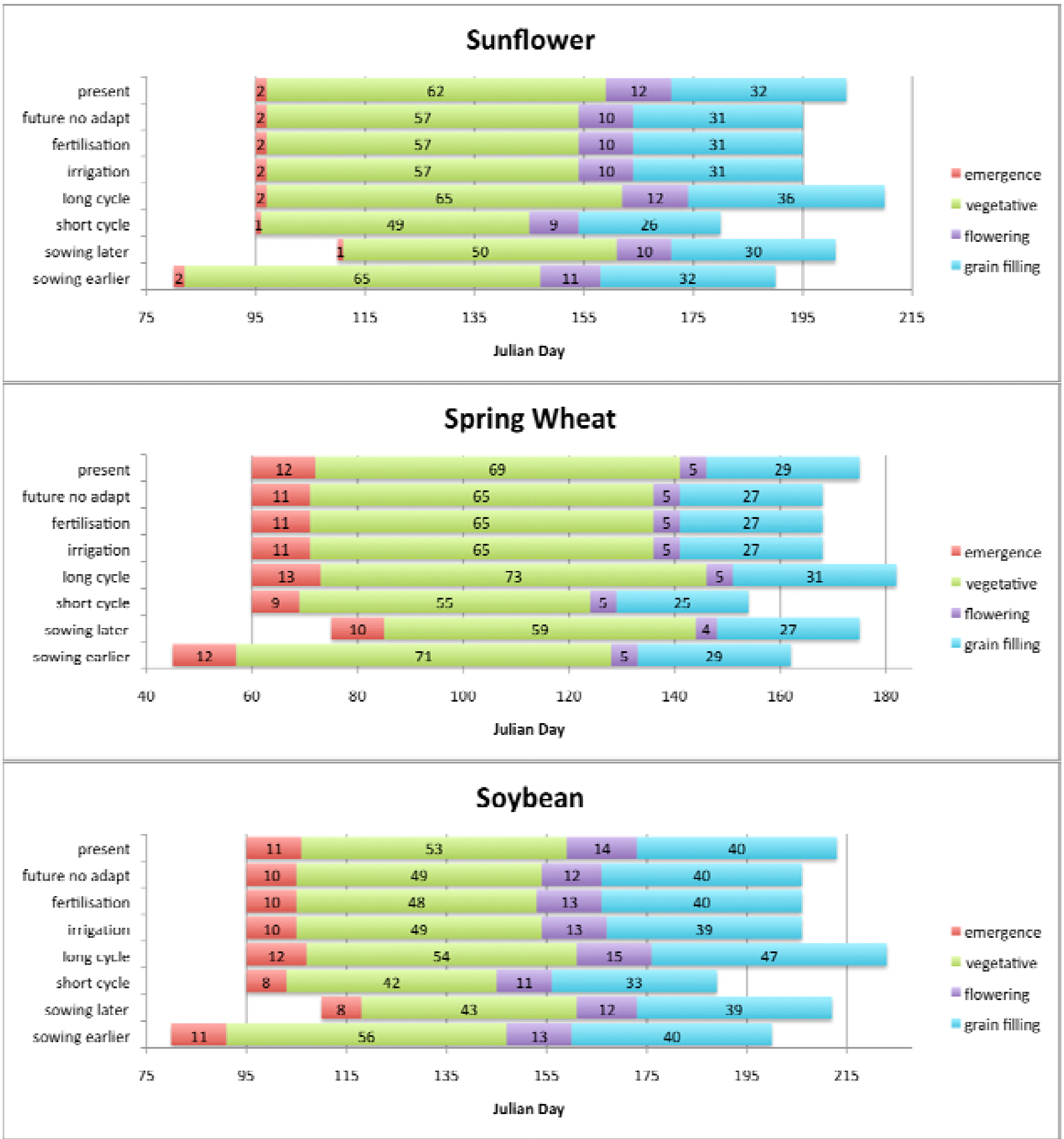
Spring wheat: interestingly, this crop showed the best results while not adapting (no significant changes in yield respect to present period, besides a small area in the north of the basin) and especially with irrigation (I); the latter resulted in a slight increase in the eastern and central areas (+6.6% in average); fertilization (IF) produced the same results than no adapting. All the other measures produced a slight decrease in the final yield, except the use of longer vegetative cycle cultivars, which caused a more severe decrease of production (-10.2% in average) over the whole basin, occurring the maturation of the seeds during a more dry and hot period.

Soybean: simulations showed that this legume might be strongly affected by climate change (from -32% in average using longer cycle cultivars to -13.4% when sowing earlier), with consistent reduction in final yield in almost the whole basin for all the different strategies considered. Only the use of cultivars with shorter vegetative cycle (SC) resulted in no changes (with a slight increase in the yield of two spots situated in the western part of the basin): this because the plant is avoiding the combined effect of drought and heat waves by anticipating the maturation. On the contrary, the cultivars with longer cycle (LC) had the most severe decrease in yield, among the possible measures.

Corn: in our simulations, this crop was the most negatively affected by climate change, with decrease of yield –no significant differences due to the choice of adaptation measures- over the whole basin, ranging from -46.9% to -24% in average. In the simulations the corn was always irrigated (in fact there are no differences between the results of FNA and I options). The crop was particularly affected by the adverse conditions that are projected to occur during the future summers in GRB, as it may be inferred by the slightly better results achieved when both implementing early sowing (-29.6%) and using shorter cycle cultivars (-24%).

Phenological phases as simulated by CropSYST in present and future scenario





3.2.4 Conclusions

Climate change impacts on GRB agriculture are projected to be significant. In particular, climate conditions of future summers will severely harm the production of spring-sowed crops such as sunflower. The increase in extreme events frequency will exacerbate the combined effects of droughts and high temperatures during late spring and summer.

As an adaptation strategy, irrigation showed the best results, with increases in the yields of Sunflower and wheat, both winter and spring sowed. However, it should be noticed that climate change is projected to progressively decrease water availability in GRB, with consequent increase in conflicting interests of the different sectors, such as agriculture, tourism and industry. Therefore, this adaptation measure may be considered not feasible unless significant improvements in water use efficiency will be achieved; however, both institutional and technological support and efforts will be indispensable.

The cultivation of cultivars of sunflower with shorter vegetative cycle, so to skip the most adverse periods of future summers, showed good performances, with increase in the yields over the whole GRB. Similar results were obtained for soybean.

The other adaptation measures did not produce significant positive effects on yields.

The integration of these results in more complex simulation models, with regard to economic, technological, demographical and land use aspects, will allow a broader view of adaptation measures, both in agriculture and other sectors, and more structured long term strategies to cope with climate change.

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3.3 Diversification of agricultural crops to adapt to climate change

Werners, S. E., F. Incerti, M. Bindi, M. Moriondo and F. Cots (2007) Diversification of Agricultural Crops to Adapt to Climate Change in the Guadiana River Basin. In Proceedings ICCC 2007, Hong Kong.

Summary: Adaptation is gaining attention as an inevitable answer to the challenges posed by climate change. The increasingly uncertain climatic conditions to which actors are exposed are becoming a constraint for their well-being. This paper looks at diversification as a key factor in reducing risk and means of coping with an uncertain climate. The aim of this work is to identify combinations of agricultural crops that reduce current and future climate related risks in the Guadiana River Basin. The Guadiana is a transboundary river between Spain and Portugal. The paper uses the variance of the revenue of agricultural crops as a proxy for climate risk, associating minimum variance with a region that is well adapted to the climatic conditions. The paper assesses risks as a function of the key agricultural crops and the climatic conditions that the Guadiana is subjected to. Crop yields under different climatic conditions are simulated by linking climate scenarios from General Circulation Models to the regional crop simulation model CropSyst. Borrowing from economic theory, the paper shows what cropping patterns reduce climate related risk. Crops with yields that have a low correlation provide the highest potential to reduce climate risks. Comparing model simulations of the scenario period 1961-1990 to the period 2071-2100, results suggest that the climate will have modest effects on the average crop yield, but will significantly reduce the variance of crop yields and change crop yield correlation. This changes the cropping pattern that provides the highest risk security.

3.4 Climate change and tourism: the Guadiana region

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3.4.1 Context and driving forces for change

Tourism is an important economic sector for many areas of the world and is a significant source of revenue for Europe, with the region accounting for 53% of the global market in 2008 (UNWTO World Tourism Barometer, January 2009). The Mediterranean stands out as the most popular destination within Europe with over 179 million visitors in that same year, many heading there from Northern Europe drawn by warmer summer climes, abundant and guaranteed sunshine, and the traditional 'sun and sand' holiday offer (Boniface & Cooper, 2005). However, tourism is also one of the economic sectors that has been identified as particularly vulnerable to future climate change (World Tourism Organisation, 2003; Higham and Hall, 2005; Becken and Hay, 2007), with the Mediterranean region singled out as one of the critical 'hot spots' most at risk from climate-related hazards (IPCC, 2007). Predicted impacts include: increased temperatures, changing precipitation patterns, sea level rise and storm surge, and an increase in both the occurrence and intensity of extreme events.

Studies attempting to measure the attractiveness of tourist destinations have shown that climate is one of the most important attributes (see for example: Bigano, Hamilton & Tol, 2008).The substantial north – south flow of tourists in Europe illustrates the heavy reliance of the Mediterranean visitor economy on climate, which ultimately defines the length and quality of tourism seasons (of critical importance to private sector operatives in the region), and even the competitive relationship between the Mediterranean and other regional destinations (World Tourism Organisation, 2003). The majority of scientific literature dealing with the interactions between climate change and tourism at the macro scale has tended to focus on one key variable: that of *temperature* (and associated thermal comfort), with research results predicting a marked deterioration in the appeal of the Mediterranean during the summer months as a result of increased temperature (see for example: Perry 2000; Agnew & Palutikof, 2001; Casimiro & Calheiros, 2007). Coupling the rise in average temperatures with an increasing incidence of extreme heat periods - i.e. the number of days exceeding 40°C - this is likely to make many countries in the Mediterranean region simply too hot for the comfort of most holiday-makers during the summer period (Nicholls, 2006). The potential for a significant slowing of the north – south flow of tourists is further enhanced by a concurrent improvement in the summer conditions experienced by regions in more northern latitudes (see Figure 3.2). Whilst predictions point to substantial declines in visitation during the peak summer season, some commentaries also hold out the hope that this fall may be partially offset by shifts to the 'shoulder' months in spring and autumn. However, seasonality is considered of critical importance for the profitability of the Mediterranean region (Amelung, Nicholls & Viner, 2007) and any such shift will have repercussions for local managerial practice and even the repackaging of strategic marketing campaigns (Nicholls, 2006).

That said, future outcomes remain unpredictable as little is currently known about how variables other than climate are likely to affect visitor behaviour in the future. Indeed, research carried out in the UK suggests that socio-economic influences and trends, such as increased disposable income, the anticipated rise in the number of retired people, and a change in the value we place upon different types of tourism (such as nature-based activity) may be equally important factors in determining how and where people choose to holiday (McEvoy *et al*, 2006). The importance of social and economic drivers is well-highlighted by the current economic crisis which triggered a 'drastic slowing of the growth in international tourism' in the latter part of 2008 (UNWTO World Tourism Barometer, January 2009). Uncertainties relating to climate preferences and loyalty to specific destinations add further complications to any future projections (UNWTO-UNEP-WMO, 2008).

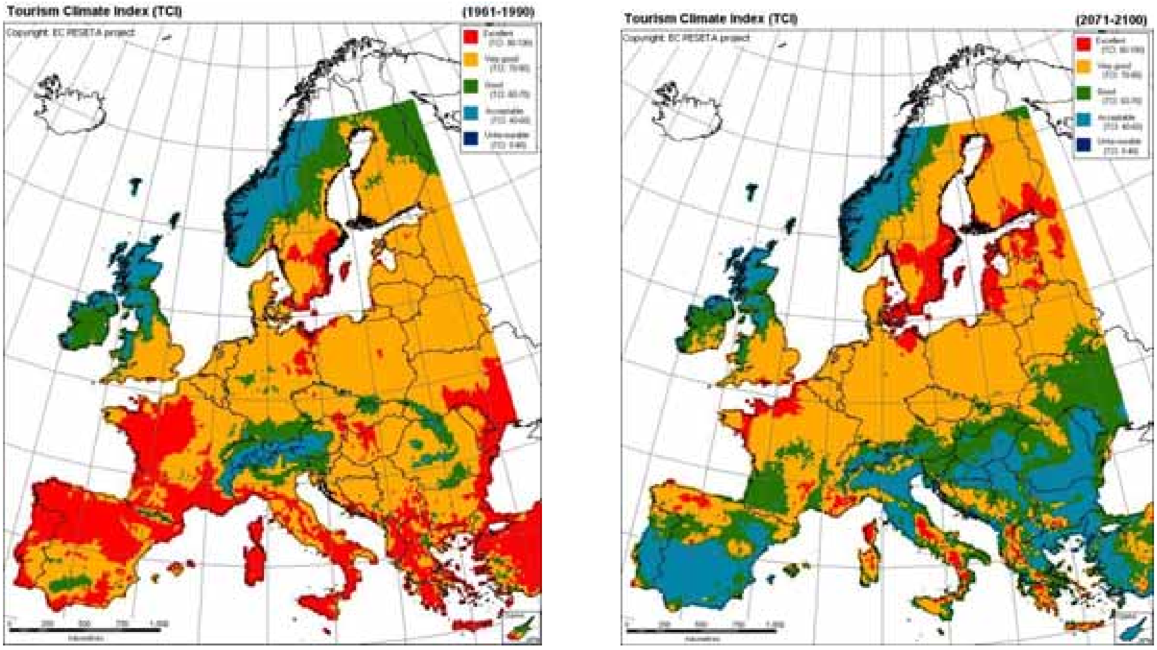

Figure 3.2: Simulated conditions for summer tourism in Europe for 1961-1990 (left) and 2071-2100 (right) according to the IPCC high-emissions scenario (from Peseta project)

Whilst temperature has been the primary focus of academic analysis it is clear that there are other climate impacts likely to adversely affect the Mediterranean tourism industry. In particular, ***water shortage*** is already a structural characteristic of the Guadiana region, and is a problem that is likely to become all the more acute in the coming years (Tàbara *et al*, 2009). This will have implications for sustaining tourism infrastructure especially large developments on the coast (tourists being responsible for high per capita resource consumption – McEvoy, 2005) and other water intensive activities such as golf courses which have become prevalent on the Spanish side of the border in recent years. Shortages may well lead to increased tensions and potential conflict between different regional land uses such as tourism, agriculture, urban development etc. These tensions formed the focal point of discussions in an ADAM stakeholder workshop held in the Guadiana region in 2006 (ADAM project, 2007), with participants citing the issue of water availability as currently one of the most contentious (it was noted that agricultural practice accounts for some 80% of water used in the region). The cultivation of 'water thirsty' crops and the over-exploitation of groundwater resources by both farmers and golf courses were cited as particular problems. Interestingly, competition for land between tourism and agriculture was also highlighted by workshop attendees. Indeed, it was suggested that the land available for tourism activities often depends on the leftover space not used for agriculture (*ibid*).

Climate change will not only have implications for visitor behaviour and regional carrying capacity but will also impact on the landscapes that attract visitors in the first place. A combination of increased temperature and periods of drought will heighten the risk of ***wild-fires***, as already evidenced by the damage caused by the extensive forest fires that blighted southern Europe during the 2005 drought period. Thousands of hectares of forests were destroyed in this extreme event, with Spain and Portugal severely affected[12]. Without careful management of the 'flammability' of vulnerable landscapes (and changes to counterproductive CAP subsidies which inadvertently promote the wrong type of agricultural practice for future climatic conditions) such events could become more commonplace. Not only will this put human lives at risk, but serious fires can also cause erosion scars, affect water quality, and damage fragile ecosystems. This highlights the necessity of sustaining the environmental capacity of those landscapes that are most valued, ultimately requiring strategic forward planning and informed local land management. Other climate-related impacts will also need to be planned for; including ***sea level rise*** and ***storm surges*** which will affect coastal areas and an anticipated increase in the prevalence of ***pests and diseases*** in the region. Water, food, and vector-borne diseases; as well as the re-introduction of malaria and West Nile virus fever, have all been highlighted as being of potential concern (Casimiro & Calheiros, 2007).

When setting the context for tourism in Guadiana it is also important to note that there are different types of tourism offer. Although the traditional beach holiday is the most obvious lure of the region, attractive rural landscapes, cultural heritage and a Mediterranean lifestyle, contribute additional opportunities for diverse visitor preferences. This diversity was stressed at the stakeholder workshop where local stakeholders identified four distinct tourism offers - coastal, rural, cultural, and the specialised activity of golf (ADAM project, 2007). On the Spanish-side, development has tended towards catering for the mass-market 'sun and sand' tourism segment, with associated large-scale infrastructure. This focus has resulted in substantial urbanisation in recent years, and there are concerns that excessive coastal development is causing a reduction in beach area with negative implications for visitors' perceptions of the area. This view is supported by statistics that show that urban sprawl in Spanish areas increased by 22% in just six years (2000-2005)[13]. Whilst this development has brought economic benefits, there has been recent criticism of lax development laws[14] (and their enforcement) and increasing concerns that this development is not only affecting visitor perceptions but is also undermining the resilience of the dune systems and wetland areas, with short-term economic development taking precedence over the protection of the environmental integrity of the coastal zone (Bramwell, 2004; ADAM project, 2007). As brought up in discussions at the ADAM workshop, voices are also beginning to question the type of tourist that Guadiana would like to accommodate in the future, suggesting that the drinking and partying culture imported from countries such as the UK and Germany may act against attracting other types of visitor.

As such, whilst beach holidays remain the most high-profile offer of the Guadiana region, interest in other forms of tourism for inland, more rural, areas is increasing (particularly on the Portuguese side of the border). Here, the promotion of more sustainable forms of tourism is not only seen as more fitting for the natural landscape, but is also considered to have the potential to support local livelihoods in the future. Findings from the ADAM stakeholder workshops suggest that the diversification of activities could be a useful option for maintaining visitor numbers to

[12] http://news.bbc.co.uk/2/hi/europe/4172472.stm

[13] http://www.elpais.com/articulo/espana/Comunidad/Valenciana/construyo/costa/solo/anos/elpepiesp/20090323elpepinac_6/Tes (Spanish)

[14] Criticism has even been voiced at the EU level - http://news.bbc.co.uk/2/hi/europe/7965912.stm

the region, whilst also adapting to a changing climate. This trend towards agro-tourism, and improved linkages between tourism and traditional land use practice, is considered important for drawing international visitors to the region, enabling them to experience local culture and even try out agricultural produce such as food and drink. A prime example of this new emphasis on gastronomy is highlighted by the regional handmade and agricultural products which are branded 'Marca Parque Natural' in Andalucia. In support of this diversification process, the Portuguese Government is attempting to retain the character of rural areas by providing support for small-scale agricultural practice. In addition it is hoped that these measures will also counteract the migration of young people out of those rural areas that are considered the most economically deprived.

As well as having a strong cultural identity, any move towards greater promotion of nature-based tourism is further boosted by the presence of many areas of natural beauty in the region, including nature parks, Nature2000 areas, and bird sanctuaries (e.g. the Vale do Guadiana National Park and Guadiana Estuary or Castro Marim National Park)[15]. These diverse landscapes are home to a spectacular array of flora and fauna and could support a range of outdoor activities as well as underpinning the development of more sustainable forms of tourism. However, careful land management and conservation will be needed as less water will have serious implications for some of the most sensitive sites. Pressure is already mounting on pristine natural environments in the Guadiana basin as evidenced by the example of the Tablas de Daimiel National Park. In this case, exploitation of the aquifers for irrigation purposes has led to a 'drying out' of wetlands and hence the site has become an unsuitable environment for birds (and hence bird-watchers).

As discussed in this introductory section, climate change will not only have implications for visitor behaviour, it will also have direct impacts on the landscape (with considerable implications for rural areas of natural beauty) with carrying capacity likely to be affected by increasing water scarcity (impairing the regions ability to accommodate high levels of visitors). In light of the evidence, it is clear that Guadiana is likely to be subject to serious (and multiple) stressors in the future, with risks further exaggerated by the region's high level of economic dependence on tourism incomes (Deutsche Bank Research, 2008). Adaptation is therefore vital if a healthy visitor economy is to be sustained in the longer term. This pressing concern is reflected in the sustainable development strategy for the Mediterranean, which states "with a degraded environment, the Mediterranean is in grave danger of losing the main assets which make it so unique, especially in agriculture and tourism" (UNEP/MAP, 2005: p3).

3.4.2 The institutional dimension

To better understand tourism in the Guadiana context it is necessary to consider both the different sets of actors and also the institutions that provide the context in which they operate i.e. the system of rules which influence actor behaviour and determine the character of their practices (McEvoy, Lonsdale & Matczak, 2008). Dealing with the actors in the first instance, four important groups (operating and interacting across different spatial scales) can be identified. The

[15] Websites promoting rural tourism highlight the considerable offer of the region: http://www.iberianature.com/

first grouping is comprised of the tourists themselves. Of all the actors, these ultimately have the greatest flexibility, with considerable choice concerning where to go, what activities to participate in, and even when to travel (Wall, 2007). However, it is also important to distinguish between two sets of visitors to the region: international and domestic. These can have inherently different characteristics, display different preferences for their type of holiday, and even react differently to changes in climate i.e. whilst the international segment is suggested as potentially sensitive to any change in temperature regime (both in Guadiana and their place of origin), domestic visitor flows may in reality prove more resilient to change. In such cases, pull factors such as culture and lifestyle may act as an important counter-balance to the inconvenience of higher temperatures, especially when reinforced by the implementation of local adaptation measures. This was emphasised at the ADAM workshop with the example of Portuguese people from outside the Guadiana region renting holiday homes for two-week holiday periods. This would suggest that a greater focus on domestic tourism in the future might help to build in additional resilience into the local visitor economy.

The second grouping consists of those private sector operators (both organisations and individuals) that rely primarily on tourism for their livelihoods. However, in this case it is important to understand that tourism is not one coherent industry, rather is represented by economic activity across a wide spectrum of related industries - for example; transport, hospitality, retailing etc (Evans *et al*, 2001). Generally speaking, the majority of businesses are small and medium-sized enterprises (Spain having larger type organisations mainly tailored to the 'sun and sand' mass market, with Portugal tending to have smaller scale operations, particularly in rural locations). For those catering to the immediate demands of visitors, the flexibility available to tourists under changing climatic conditions may pose operational problems in the future as much of their capital investment is in infrastructure (and other tourism provisions) that tend to be fixed in geographical location, and therefore not easily liquidated for re-investment elsewhere should conditions deteriorate. As noted by Wall (2007), if the quality of recreational experience is degraded, or the length of season shortens, then there are likely to be considerable economic dislocations for recreational businesses and the communities on which they depend. That said, adaptation measures may help to reduce some of the worst impacts (e.g. additional shading in tourism facilities, education of staff and visitors, changing land management practice in rural locations etc), and as a consequence new business opportunities may even open up to cater for this demand for new products and services.

Other important actors involved with tourism are those operating at a more strategic level, specifically those policy-makers with responsibility for tourism strategies, management, and marketing at the regional and national scales. Their role is likely to prove critical in providing the resources that help operators determine the risks of climate change to their business (information needs to be in a format suitable for the end-user) and for ensuring that enabling mechanisms are in place that will assist individual adaptation 'on the ground'. Furthermore, their strategic overview and direction is of utmost importance as many small businesses exist primarily on seasonal takings, often operate with very limited planning horizons, and as such tend to be reactive rather than proactive to managing change. Ultimately, sustaining the regional visitor economy will depend on promoting a greater proactive stance to maintaining the quality of the environment (and visitor experience) in the face of both climate and non-climate change. Where management good practice exists, this needs to be supported. The re-packaging of tourism products may also be needed as climatic conditions, and visitor preferences, change over time.

With multi-actors operating at different spatial scales, there is considerable institutional complexity involved. At the national scale, climate change arrangements include the Portuguese National Climate Change Programme (2001) and the Spanish National Adaptation Plan (2006). Implementation of these programmes is the responsibility of several newly created national bodies, such as the Portuguese Climate Change Commission, the Spanish Inter-ministerial Group on Climate Change and the National Council on Climate Change. For tourism, Portugal is guided by the 2007 'National Strategic Plan for Tourism' (PENT) which sets out the vision for tourism until 2015, whereas Spain has recently launched a strategic document 'Tourism Plan Horizon 2020' which highlights the pressures facing coastal tourism in particular and places a strong emphasis on sustainability, diversification, and enticing visitors to less well-known locations[16]. It is also interesting to note that the Spanish regions have a much higher degree of autonomy than their Portuguese counterparts.

ADAM research activity in the Guadiana region has highlighted the close interplay between tourism and other important sectors, particularly with agriculture and water supply. Due to the diffuse nature of tourism activity across the region it is therefore necessary to also consider a fourth grouping: those actors that are not directly involved with tourism but whose activity may overlap with aspects of the local visitor economy. Interactions between these different sets of actors can either be negative as in the case of competition for land and water, or positive as highlighted by growing interest in the potential for marrying sustainable tourism with agricultural diversification. As climate change will affect a range of sectors (water resources, agriculture, biodiversity, health, insurance etc), with knock-on implications for tourism practice, it is clear that forward planning for tourism cannot be taken in isolation. Decision-makers need to move beyond a sectoral 'silo' approach to consider the Guadiana region as a whole system, working to ensure that development policies are integrated horizontally as well as vertically. A prime example of this is the sustainable management of the rural landscape. In this case, two strategic initiatives originating at the EU level are likely to have profound implications for land use and the state of the landscape, which in turn will have a strong influence on recreational carrying capacity and the quality of visitor experience. The first of these is the reform of the Common Agricultural Policy (CAP) which is promoting structural changes to the agricultural economy. Though diversification towards tourism, nature conservation, farm tours and sale of locally produced food is becoming more evident, there are further significant opportunities to promote agricultural restructuring that more closely matches biodiversity and nature-based tourism aims. The Water Framework Directive (WFD) is the second influential policy emanating from the supra-national level. Its emphasis on greater stakeholder participation is likely to prove to be of enormous value as it enables different actors to come together in a collaborative 'learning' environment to discuss the

[16] http://www.eturbonews.com/308/spain-unveils-sustainable-tourism-plan

potential impacts of future climate change on water availability and related risks to their business, to debate and build consensus on alternative adaptation strategies, and to begin to explore the roles and responsibilities of different actors in achieving a more integrated regional development strategy.

3.4.3 Adaptation outcomes

As noted, tourist destinations are coupled human-environment systems, with climate change adding a further layer of complexity to an already complex system (Becken & Hay, 2007). This means that climate change will act as only one of a multitude of stressors, and forward planning for tourism will therefore need to take an integrated and holistic approach to adaptation. The predominant focus of research activity to date has been on increasing temperatures, and although there is little that can be done by local operators to alter international visitor perceptions in this regard, strategic marketing initiatives may benefit from a shift in focus that reinforces the positive aspects of the Guadiana region, for example:

- Target groups that are less sensitive to changes in climate, particularly temperature (one option being a greater reliance on domestic holiday makers);
- Diversify the tourism offer to less climate dependent activities – nature-based, cultural, specialised activity etc;
- Consider the potential vulnerability of locations, and direct visitors to more robust sites (demand management);
- Promote visits in the shoulder months.

Consideration of water availability, and its influence on recreational carrying capacity, will also be critical. In this regard, strategic responses will be needed beyond the tourism sector, ultimately requiring both supply and demand side adaptation measures. On the supply side, technical options such as water transfer between regions, and the use of desalinisation plants as a source of alternative supply (though this remains a contentious option due to high energy requirements), are being investigated for their potential application in the region. As water availability becomes further constrained under a changing climate, the potential for conflict between different sectors (even between different countries) will be heightened. As such, new institutional arrangements may be necessary to provide a suitable environment for consensus building and the sustainable management of this valuable resource. On the demand side, the tourism industry itself can make a valuable contribution to these goals by ensuring that the water efficiency of facilities and operations is improved through an increased uptake of conservation measures e.g. rainwater storage, recycling, use of water saving devises etc. Education and awareness-raising may well have a greater role to play here under changing conditions.

There are several other options that could potentially benefit strategic adaptation goals for Guadiana in the longer term. Some examples include:

- Strengthened strategic planning and development control. There are concerns that current legislation doesn't work well, that there is a lack of coordination between administrations, and at the current time there is little consideration of climate risks. This was highlighted by the example of golf courses, with conflict evident between different Government departments (ADAM Project, 2007);

- More effective use of existing regulatory instruments (for instance, integrating climate change considerations into EIA procedures for assessing tourism infrastructure);
- Promote the application of integrated tourism carrying capacity assessment techniques as a tool for tourism planning in light of climate risks;
- Use of insurance mechanisms to transfer the risk of extreme events;
- Improving preparedness for extreme events through awareness raising and closer liaison between risk management teams, health officials, and members of the local tourism industry.

Whilst adaptation to climate change can take place at various scales, climate risks are commonly context specific (a function of hazard type, vulnerability of elements at risk, and exposure) and hence the implementation of adaptation measures will often be at the local or site level. Furthermore, when dealing with climate change and tourism it is also necessary to factor in the different activities undertaken by visitors, as these will be influenced by weather parameters to varying degrees (Wall, 2007). Taking each of the tourism offers that were identified in Guadiana in turn, discussion now focuses on some examples of adaptation options that are available for each (though recognising that some measures may be applicable across cases), before then finally analysing some of the underlying institutional processes that can either assist implementation, or alternatively act as barriers to action (section 4).

The first example is that of *cultural* tourism. Due to the type of activity involved, this is likely to be fairly resilient to climate change impacts, and further promotion of this type of visitor activity may itself act as a useful adaptation strategy for the region through diversification and the promotion of alternative activities e.g. promotion of festivals, agricultural fairs, museums etc. Physical adaptation is likely to involve measures such as the upgrading of infrastructure and facilities, ensuring access to shade etc, in order to maintain visitor comfort during periods of high temperature.

The second offer relates to another specialised activity, *golf*, though this is considered a more contentious issue in the region. On the one hand, some regional stakeholders are keen for more golf courses to be built (seen as attracting wealthy visitors), whereas on the other hand opponents are critical of their environmental impact; particularly the high water demand for irrigation purposes (sometimes obtained illegally from groundwater sources), preferring instead to advocate greater efforts at providing alternative activities (ADAM Project, 2007). Whilst industry groups recognise that golf courses are often portrayed in negative terms (personal communication, Golf Environment Organisation, 2006) – many people associating golf courses with unsustainable practice, both environmentally (irrigation and overuse of water, use of pesticides, waste etc) and socially (exclusivity) – efforts are underway by the European umbrella organisation 'Golf Environment Organisation' to try and improve management practice through the provision of environmental best practice information, a new online certification scheme, and by contributing to land use planning and development control decisions[17]. They are also supportive of more

[17] http://www.golfenvironment.org/

widespread application of Environmental Impact Assessment (EIA) for new developments. Interestingly, they have also positioned themselves as a knowledge broker, facilitating exchanges and learning between representatives from the golf industry, scientists, environmentalists, and policy-makers (most recently exemplified by their involvement in an initiative to promote a sustainable model for new golfing facilities). However, practical evidence of improved resource efficiency, particularly the use of water, will be a key adaptation measure for this recreational activity, as well as being a critical trigger for wider social acceptability.

The third, and most popular, Guadiana offer is ***coastal*** tourism. As noted previously, coastal areas are particularly vulnerable to climate change, with potential exposure to extreme climate events and sea level rise, a vulnerability exacerbated in the region by the presence of other stressors (extensive tourism development on the shoreline is a particular problem in the region). As such, one primary adaptation measure will be more rigorous control of where development is allowed to occur. This will not only improve landscape aesthetics, maintaining the integrity of coastal ecosystems can also provide a natural defence to storm surges and hence reduce the risk of inundation. In reality, although authorities in the Guadiana region have attempted to legislate against sprawl, developers often ignore these efforts and continue to build in unsuitable locations with little penalty (the legislation in Spain applies a 100m limit for buildings near the coast, whereas in Portugal it is 500m - though the Portuguese legislation is not considered effective). More effective enforcement will ultimately be necessary, assets may need to be better protected by new or improved sea defences, and in the worst cases dismantling and relocation of infrastructure may also be required. The bonus here is on the public realm to ensure that planning regulations and development control measures take climate change considerations into account, and that enforcement is seen as effective.

Adapting to heat will also need to be addressed by those involved with the local visitor economy. For the public sector this could involve the promotion of heat programmes; based on an early warning system for extreme events and awareness raising efforts aimed at tourism businesses, their staff, and even the tourists themselves. The private sector also has a role to play by ensuring that facilities are designed to cope with heat without resorting to excessive use of air conditioning (a classic case of mal-adaptation). This can be achieved through the design and upgrading of individual buildings (shading and passive ventilation) though landscaping schemes that improve the quality and functioning of public areas would also be a valuable adaptation response to ensure continued quality of visitor experience. On a final note, although insurance is often cited as a useful financial mechanism for spreading risk, the cost of insurance is likely to rise as a result of the increasing frequency and severity of extreme weather events (Mills, Roth & Lecomte, 2005), with implications for small-scale tourism operators in the longer term.

The final offer, ***rural*** tourism, is considered to hold considerable potential for the region. Indeed, many of the regional landscapes that appeal to visitors are currently managed by traditional agricultural practice, and a greater emphasis on the multi-functionality of the land (bringing together tourism, nature and agricultural concerns) could be of enormous benefit to the adaptation agenda[18]. Engagement with stakeholders during the ADAM project reinforced this opinion with attendees highlighting the opportunities for exploiting the integral connection between tourism and agriculture, not only helping to strengthen long-term sustainable development objectives for the region but also reducing over-dependence on one economic activity. Promoting and modernising the traditional 'dehesa' (Spain) and 'montado' (Portugal) ecosystems was cited as one specific example of potential diversification. However, it was recognised that new crops and management systems may also be needed to ensure a greater local resilience to climate change. Changing practice would need to be supported by evidence and data on the effectiveness of different drought and heat resistant plants (and management systems) in order to best inform any adaptation response by local stakeholders. Whichever crop is produced, stakeholders also made clear that support for local businesses in accessing local and international markets was vital. Encouraging tourism businesses to source products from local producers is one potential avenue in this regard.

Whilst large-scale tourism developments in the coastal zone raise issues of water availability in the longer term, in more rural locations consideration of the water issue is also centred on protecting river systems, both in terms of quantity and quality, in order to boost the value of rural tourism. For the landscape more generally, it is recognised that integrated measures to protect the pristine natural environment are needed, and that this will ultimately require greater levels of partnership working (within and between different sectors). Research conducted in the UK recommended that where they exist, proven management mechanisms should be supported to maximise local adaptive capacity (McEvoy *et al*, 2006). However, in the Guadiana context, there is a further and important 'transboundary' issue, suggesting the need for new institutional arrangements that promote consensus building not only between different competing uses but also different countries. More detail on the transboundary issue, and discussion of the adaptation role of policy entrepreneurs, is available in McEvoy *et al* (2009) and Cots *et al* (in press).

3.4.4 Adaptation as a process

A common thread running through ADAM research findings is the importance of 'learning to adapt' (McEvoy, Lonsdale & Matczak, 2008). Therefore as well as considering specific adaptation measures, institutional mechanisms that either enable or hinder implementation also need to be considered i.e. achieving a better understanding of adaptation as a process. Furthermore, most analytical frameworks now recognise the iterative nature of adaptation and therefore a need for adaptation strategies to act as 'evolving' instruments as new knowledge becomes mainstreamed, rather than a policy end point (McEvoy *et al*, submitted; Murray *et al*, 2008).

In the first instance, it needs to be recognised that adaptation responses will ultimately reflect how risk is perceived by individual actors, and the degree to which they are either risk averse or accepting of risk. International studies focusing on the tourism industry have tended to find that there are relatively low levels of concern amongst stakeholders and as a result there has been limited application of scientific data on weather, climate change scenarios etc. to inform long term strategic planning (Murray *et al*, 2008). To a large extent this is due to the small-scale and

[18] A critical outside influence will be structural changes in the agricultural economy in response to CAP reform.

fragmented nature of the tourism industry and the common practice of dealing with contingencies as they arise in a reactive manner. This was found to be the case in the Guadiana region, with stakeholders tending to frame events such as heat waves and droughts in the context of current day hazards rather than relating these extreme events to the more complex issue of climate change (ADAM Project, 2007). That said, at the strategic level there are signs of a greater appreciation of the potential consequences of future climate change both for the tourism industry as well as regional development more generally. Whilst there are signs that risk perceptions in the region are beginning to shift (a combination of personal experience, media exposure, and greater levels of awareness raising in the region) it is clear that change is happening from a relatively low baseline and there are real opportunities for improving this situation yet further.

Once actors become aware of the risks, and are willing to adapt, the issue then becomes one of building local capacity (McEvoy *et al*, submitted). Key resources for more informed decision-making include knowledge transfer and access to information, participation mechanisms, and 'spaces' for learning and consensus building (McEvoy, Lonsdale & Matczak, 2008). In terms of knowledge, scientific assessments of risk and vulnerability obviously have a role to play (including the development of replicable methodologies and sharing of data), however science on its own cannot provide all the answers and new forms of engagement between scientists, policy-makers, and the wider stakeholder community are also needed if the complexities of the climate change issue are to be addressed effectively. This 'opening up' of the assessment process is also supported by others; for example Schröter, Polsky, and Patt (2005) argue that vulnerability assessments should i) be derived from multiple disciplines and stakeholder participation, ii) be place specific, iii) consider multiple interacting stresses, iv) take into account differential adaptive capacity, and v) be prospective as well as historical. Such an integrated approach was one adopted by ADAM research activity (exemplified by the two stakeholder workshops and interviews undertaken), though local participation has also been a critical component of other contemporary research activity which has been carried out in the region recently. It is clear that these forms of engagement can only benefit the transfer of knowledge and informal interactions between different stakeholders.

An increased emphasis on participatory approaches, especially the promotion of an inclusive and transparent process, is considered as a crucial element in the building of local adaptive capacity. For instance, the AIACC project (2007)[19] found that existing knowledge networks were often incomplete and lacked coordination, resulting in substantial gaps in awareness and understanding of climate risks by decision-makers. One recommendation coming out from this work was the greater promotion of participatory processes in order to ensure the generation and communication of knowledge that is relevant, credible and co-produced by stakeholders. These findings are reinforced by tourism studies that cite evidence that the effectiveness of relationships established between universities, public and quasi-public bodies, and affected stakeholder communities, can contribute to improvements in the decision-making process and ensure the production of user friendly data in support of evidenced-based responses (see for example: McEvoy *et al*, 2006). In the specific case of Guadiana ensuring engagement with a wide range of stakeholders is not only important for ensuring that the considerable experience of tourism actors

[19] http://www.aiaccproject.org/

at coping with current and past variability in climate is not overlooked, but also the many linkages between different sectors and activities necessitates the exploitation of local knowledge for informing effective, and locally acceptable, adaptation measures. Promisingly, greater levels of participation are increasingly evident in Guadiana with the voices of actors previously excluded from decision-making processes now being heard (Cots *et al*, submitted). Academics and NGOs are two prominent groups in this regard.

More strategic support aimed at building adaptive capacity was highlighted as particularly important in the Guadiana context, with workshop participants emphasising the need for greater levels of awareness raising, better coordination of policies and between actors, and more support for promoting more sustainable activity (often small scale tourism businesses). Indeed, it was felt that a lack of coordination between policies (and different actors) is currently hindering adaptation objectives. For example, one interviewee thought although rural-based tourism holds significant potential to boost regional diversification, the lack of coordination of aid programmes (in contrast to the considerable support that is given to construction and development companies) was a major barrier to be overcome.

3.4.5 Conclusions

To conclude, it is clear that the implications of climate change (in combination with other stressors) are complex and are likely to be significant for the Guadiana region over the coming decades. This was also illustrated by an assessment carried out by Deustche Bank Research (2008) which labelled both Spain and Portugal as significant 'losers' based on modelling climate change impacts and percentage of GDP from tourism. In light of climate threats, tourism actors in the region will need greater appreciation of future risks and develop better-informed adaptation responses. As noted, each tourism offer will be affected in different ways and will need to implement measures based on their individual circumstances and contexts. Intervention will be needed at different scales:

- Operational / individual facilities: those actors reliant on the tourism trade in the Guadiana region will need to address climate challenges if they are to avoid negative impacts on their business (e.g. infrastructure damage, increased operational costs etc) and to build in resilience into their activities to ensure a sustainable livelihood in the longer term. Effective forward planning and management will be needed - facilities will be affected and investment is likely to be needed in response to climate change;
- Landscape: multiple stressors will place increasing pressure on the most valued landscapes and good land management practice will become increasingly important to sustain environmental capacity;
- Regional and transboundary: at the regional scale consensus building and closer working together between different sectors will be critical, particularly in relation to the sharing of increasingly scarce water resources. In this regard, improved cross-border collaborations will also be needed.
- National: adapting tourism activity in Guadiana will not take place in a vacuum and national policies will need to ensure that enabling mechanisms are in place to support local implementation. This is clearly highlighted by the case of rural tourism potential and the perceived lack of support and resources for diversification.

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3.5 Cross border organisations as an adaptive management response to climate change

Cots, F., J. D. Tàbara, S. E. Werners, D. McEvoy and E. Roca (2009) Policy entrepreneurship as an adaptive management response to climate change in a transboundary context. The case of the Guadiana River Basin. Environmental and Planning C (accepted).

Summary: In this paper, the authors analyse the role played by cross-border organisations in the Guadiana river basin in Iberia, and the extent to which new emerging institutional arrangements carry on adaptive management practice as a response to mounting climate change risks in the river basin. Particular attention is paid to the new transboundary agencies, as promoted by the EU INTERREG programmes, and their potential for mainstreaming climate change considerations into Guadiana river basin development strategies. Results indicate that the penetration of climate change concerns into regional development policies requires a better integration of different policies and improved connectivity and coordination between multiple

actors operating across sectors, and at different spatial scales. The authors argue that the emergence of new transboundary agencies capable of performing these bridging functions is a vital ingredient for building climate adaptive capacity in these cross-border regions.

3.6 The role of institutional capacity in enabling climate change adaptation

McEvoy, D., F. Cots, K. Lonsdale, J. D. Tàbara and S. E. Werners (2007) The role of institutional capacity in enabling climate change adaptation: the case of the Guadiana River Basin. In Proceedings International Symposium on Transborder Environmental and Natural Resource Management, Kyoto, Japan.

To be published as book chapter: 'Adapting to water scarcity in a changing climate: the role of institutions in transboundary settings'

Summary: Global climate change scenarios indicate an increase in drought-affected areas over the coming decades, with arid and semi-arid areas considered particularly vulnerable. This chapter focuses on the transboundary Guadiana River Basin, where the river acts as a natural border between the neighbouring Mediterranean countries of Spain and Portugal. This case study represents a typical semi-arid region where human activity and modification of the hydrological regime over previous decades have led to increasing water scarcity and the identification of water shortage as a 'structural characteristic' of the system. Future climate change will act to amplify existing water stress, with important consequences for the availability and distribution of water between different land uses. Addressing water scarcity as an outcome of complex socio-ecological interactions, this chapter reflects on possible conflicts and convergences between different sectors and the role of institutions in pursuing multiple-goal strategies in a transborder context. This evaluation will be informed by consideration of the institutional settings conducive to adaptation, as well as a critical appraisal of horizontal, vertical and transborder policy frameworks, and their enabling role in promoting adaptation activity.

4 Inner Mongolia, Alxa region background studies

4.1 Conclusions final workshop

The second stakeholder workshop on climate change adaptation and desertification was held in Bayanhot, the capital of Alxa League, on the 19th May 2009. The program consisted of a plenary presentation and discussion of project results in the morning and early afternoon, and a discussion on particular adaptation options in three breakout groups in the second half of the afternoon. 20 stakeholders from the region participated.

Presented in the morning were:

- ADAM regional cases and main findings (Chapter 1,2 and 7)
- Inner Mongolia study and land use change (Section 4.2 and 4.3)
- Climate scenarios, impacts and adaptation in agriculture in Alxa League (Section 4.4)
- Modelling desertification and animal - ecosystem interactions (Section 4.5)
- Adaptation to desertification and ecological migration (Section 4.6 and 4.7)
- Opportunities for Integrated Climate Governance in Alxa (Section 4.8)

Results of afternoon's break out groups:

in the afternoon three adaptation options were discussed in more detail that come out strong from the questionnaires and interviews carried out as part of the Inner Mongolia case study (see also Section 4.3, 4.4 and 4.7): ecological migration, ecological restoration and economic diversification.

Group discussion: ecological migration

Participants: Jennifer West, CICERO; Mingtian Yao, Wageningen University and Research Centre (translation); Mr. Ming Xiang (President, Alxa Association of Science and Technology- AST); Mr. Yan-li Gao (Director, Alxa AST, Foreign Affairs Department); Mr. Jun-li Ma (Alxa AST, Science Popularization Department); Mr. Ju-jie Jia (Alxa SEE – Society of Entreprenuers and Ecology, a local NGO); Mr. Deng-hai Zhao, Vice Director, IM Helan Mountain NNR Management Bureau.

Participants discussed the ecological migration policy, its links to climate change adaptation and mitigation, and the challenges and opportunities they face in implementing it and dealing with climate change. Policy-makers are well aware of the need to balance ecosystem restoration and sustainable livelihoods for Alxa's inhabitants. While ecological migration in Alxa was originally implemented as a measure to deal with an acute land degradation crisis and associated livelihoods declines, participants recognised the need for a more nuanced and flexible policy that allows controlled grazing in recovered areas, and provides a range of non-farm livelihood options and training for herders. Partnerships between the government and the NGO SEE have led to successful training, capacity-building and livelihood interventions in several eco-migrant villages. The projects are supported with financing from governments, private sector, international donors, and communities themselves, and include south-south learning involving exchanges of villagers to learn from successful projects.

Climate change adaptation and mitigation technologies such as drip irrigation, and small-scale biomass, wind and solar energy projects, as well as reforestation, are being piloted in some villages to deal with new challenges arising from the transition from extensive herding to intensive farming in oasis regions. Income diversification through milk cow promotion is one example of a livelihood adaptation pilioted by SEE. Policy-makers feel that these technologies and interventions, and associated training, can be disseminated rapidly, with lower cost, and at greater scale when people are living in migrant villages, and that ecological and social problems are generally much easier to address in the villages, compared to when herders were living in dispersed settlements that were hard to reach. The fact that the government has given strong financial and policy support to dealing with climate change, and that Alxa government cooperates closely with NGOs like SEE, who in turn have legitimacy in communities and pursue a bottom-up approach, was seen to set a very promising stage for dealing with climate change challenges in the future.

Challenges that were highlighted by participants included the difficulties of one region or country addressing climate change on its own and the need for cooperation across governance levels; the need for long-term policies to deal with climate change; the need for policies to address root causes of poverty and land degradation; the need for a more flexible and nuanced ecological migration policy, the need assess the extent to which recovered regions can be grazed, the need to involve and engage communities in the work, the need for a strong government role in determining the extent and ways in which land should be used in future, and the need to rapidly develop and widely apply new climate adaptation and mitigation technologies.

Group discussion: ecological degradation, restoration and adaptation

Participants: Xingang Dai, David Tabara, Z Xiong, Y Zhang, G H Liu, Y Z Tian, L L Liu, W B Zhang

Stakeholder introduction on ecological degradation and policy:

1. The natural environmental change is the major part than human activity in Alxa;
2. The effect of climate policy implementation (including arial seeding, rainwater collection and ecological conservation, Heihe River reallocation) is very good and leads to a good grassland regeneration, for example land vegetation cover become better and better and wild animals increased in Helan mountain;
3. One of good measures on steppe regeneration is to move local habitants and animals out of the steppe or grassland.

Stakeholder position on communication & policy:

1. Policy explanation can reach every family through communication.
2. The state is the driver: The government wants to protect environment while poor herdsmen need good living condition.

Stakeholder position on coordination of multi-level policies & monitoring

1. A big national project is usually divided gradually into a lot of sub-projects and finally to persons step by step.
2. The funding currently is not enough for such a large area of Alxa. A good regeneration of surface vegetation can be found along Yellow River. If government could invest more the ecosystem would be restored under the aerial seeding and artificial rainwater. For instance, we can found that the regeneration of the vegetation has been successful in Ordos and Ningxia Hui autonomous region with rainfall below 200mm. Why not for Alxa?
3. There are effective monitoring measures in agriculture, forestry and environmental protection. A project should be usually experienced six times of check and audit. The rehabilitation would be checked after 3 years. If good it can be supported again from government.
4. There are official inspectors who often come to check and monitor the implementation of projects. For example they monitor the migration and whether they return to steppe again. The grasslands are also monitored by remote sensing pictures.

Group discussion in the afternoon: Economic diversification and risks in Alax League

Participants: Bao Ping (Grassland Station), Zhang Wenbin (Institute of Stockbreeding), Chen Lijuan (Yellow River Economic and Culture Development Research Institute), Wu Xiang Rong (Desert Association of Japan), Tian Yongzhen (Alxa Foresty Institute), Saskia Werners (Wageningen UR), Darryn McEvoy (ICIS). Interpreter: Zhang Tiehan

The most important economic sectors in Alxa include mining industry, stockbreeding and agriculture (herbs, corn and sunflower). The mining industry is a conventional production section. There are 87 different metal industries. Among of them, the Glauber's salt and salt production and processing are key mining industries in Alxa League. The other mining industries include copper, iron, non-ferrous and ferrous metal. The average income of mining industry worker is relatively low compared to the average income of Alxa. In addition, the mining industry adds to risks of climate change and ecosystem degradation. Technical development and innovation plays an important role in the mining industry.

Stockbreeding is the most important agricultural activity in Alxa. The total amount of animals is 1.8-2 million. 60%~70% of them are goats, the rest are camel, ox and horse. The goat's cashmere of Alxa is very famous and has top quality. Corn planting is an important agriculture activity. The Chinese herbs (i.e, Cong Rong, Guo Rang) production is developing very fast in the region. In the past, the herbs were collected in the wild. In recent decade, the herb planting increased fast and now 80% of herb production is planted. The farmers use seeds and water several times in a planting season. For farmers who plant or have land where herb grow naturally, 50% of their income comes from herb. The productivity (and income) of herbs strongly depends on the weather and rainfall. Normally, the herb (Cong Rong) is planted two times a year. It doesn't need a lot of human care. The farmers also plant corn, vegetables, or breed livestock. Cashmere is the main income source of the farmers in Alax. But the income of livestock farmer is facing a big risk from climate change. Normally, farmers combine corn and grass/vegetable.

More recently farmers combine farming with tourism. The income of a tourism worker is on the middle level. The risks of farming tourism are lower than in the mining industry. Farming tourism is developing fast in Alxa, because of infrastructure development, the presence of nature reserves and stimulation by the local authority through environmental protection policies such as 'Grain for Green' (see Section 4.6).

4.2 Climate impacts on land use and adaptation

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RCE-TEA, Institute of Atmospheric Physics, Chinese Academy of Sciences

4.2.1 Study area

Inner Mongolia, China's northern border autonomous region, is a long narrow strip of land sloping from northeast to southwest. It stretches 2,400 km from west to east and 1,700 km from North to South. It is the third largest among China's provinces, municipalities and autonomous regions, and the region covers an area of 1.18 million sq km, or 12.3% of the country's territory. It neighbours eight provinces and regions in its south, east and west and Mongolia and Russia in the north, with a borderline of 4,200 km (Inner Mongolia Government, http://www.neimeng.gov.cn, 2008).

Our case study area, Alxa League, is the westernmost administrative units of Inner Mongolia. The Alxa Plateau is located in north-central China, with various steppe, deserts, oasis, and mountains on it. The eastern edge of the Alxa Plateau is bordered by the Helan Mountain and the Yellow River. The Alxa Plateau is characterized by shifting sand dunes and stabilized sands with sparse vegetation. The Alxa Plateau is composed of three basic physiographic units. The eastern region consists of the Tengger Desert and the Ulan Buh Desert (Figure 4.1), which surround large areas of grassland. In the west, the Badan Jaran Desert contains large areas of transverse dunes, which represent an ancient landscape (Alxa League Statistics Bureau, 2008). The highest altitude is that of the Peak of Helan Mountain at 3556 m in the southeast, while the lowest point is that of Inggen Basin at 720 m. The average elevation on Alxa Plateau ranges from 900-1400 m.

Most of the project area is under temperate semi-arid to arid continental climate. On the Helan Mountain piedmont to the east precipitation is ~200 mm and aridity is 3-4. The precipitation gradually declines and aridity increases to the west, with lowest precipitation of less than 40 mm and highest evaporation of 4200 mm. In the westernmost part of the region, precipitation is less than 40 mm. The annual mean temperature in the project region is 6.0 to 8.5 ºC. The mean temperature for the hottest month (July) is 22.0 to 26.4 ºC; during the coldest month (January) it is -14.0 to -9.0 ºC. Accumulative warmth (>10 ºC) ranges from 3000-3500 ºC, corresponding to a length of growing season of 205-235 days, an annual solar radiation of 5873-6101 10^6 J/m^2 within 2600-3500 hours (Alxa League Statistics Bureau, 2008). Plenty of solar radiation and summer warmth combined with irrigation from the Yellow River and ground water provide a favourable agricultural climate condition, despite of the scares rainfall. Main crops are corn, sunflower, water melon, and cotton.

The low precipitation in combination with the high potential evaporation limits the possible types of land use. The growing of cereal crops and vegetables is only possible with irrigation. Since, even in this semi-arid to arid region most of the precipitation falls as heavy rain in summer, flood is a serious threat because the parched soil cannot absorb a great quantity of water in a short time. Therefore, most of the rainwater remains on the surface. The Helan mountain range is under mountainous climate, with relatively warm and dry low elevations and cool and humid high elevations. The average precipitation is 422 mm, which is as twice as in the plain. It serves as a natural shelter for the Alxa Plateau to the west and home to rich biodiversity.

Figure 4.1: Landscape of sand dunes, steppe desert, and croplands along edge of the Tengger Desert, as seen from satellite

4.2.2 Field investigation

The field investigations were conducted by examining plant community features, disturbances, and grazing intensity, etc. Vertical vegetation distribution in Helan Mountain was examined with GPS and non-plot sampling. Enclosed grasslands were sampled and compared with adjacent patches under light, moderate, and heavy grazing. Human footprints and rangeland degradation along the edge of sandy deserts were investigated (Figure 4.2).

Satellite images including AVHRR, MODIS, Landsat, Aster, and QuickBird, along with air photos and field digital pictures were processed with ENVI software and some of them were fused and assimilated to examine status and dynamics of the landscapes, to assess various land use options and human disturbances on natural ecosystems, and to identify critical locations for climate change impacts and adaptation.

Spatial patterns of land cover, vegetation greenness, and various environment related features were mapped, and inter-annual trends of vegetation production was derived from satellite data and analyzed with change detection technology.

Figure 4.2: Field investigation in heart of the Badain Jaran Desert, led by Gensuo Jia (Third from left) of CAS and Yinglong Xu (fourth from left) of CAAS

4.2.3 Climate and ecosystem dynamics

Under the semi-arid and arid climate in Alxa, steppe and desert rangeland (also known as grassland locally) count for one-third of the land cover. In addition, about 25.6% of the current croplands were originally converted from steppe (Fu et al, 2003). The desert steppe is featured with various perennials and annuals such as *Stipa breviflora*, *Aristida adscensionis*, with sparse shrubs of *Caragana stenophylla* and *Artemisia frigida*, and covers most of highland areas in the piedmont (Zhao 2007). The semi-desert is mainly distributed in eastern part of the plateau and featured with sparse short shrubs such as *Reaumuria soongorica* and *Ammopiptanthus mongolicus*, and some perennials/annuals including *Stipa glareosa*, *Allium mongolicum*. The desert vegetation covers large areas of Alxa Plateau and featured with xerophylla shrubs and semi-shrubs such as *Zygophyllum xanthoxyllum, Atraphaxis bracteata, Salsola arbuscula, Salsola oasserina, Ammopiptanthus mongolicus, Nitraria tangutorum,* and *Haloxylon ammodendron*. Hundreds of oasis wetlands dotted among those zonal ecosystems (Figure 4.3).

Figure 4.3: Landscape mosaic of sandy desert, oasis village, and steppe desert along the Helan Mountain piedmont

Figure 4.4: Blooming desert steppe vegetation in west side of the Helan Mountain

Declining biological production as a part of ongoing land degradation process is considered a severe environmental problem in Inner Mongolia. Based on ground measurements of net primary production (NPP) and primary production derived from AVHRR satellite data, mean annual primary production between 1982 and 2006 range from about 120 g/m2 in desert regions in the west (Alxa) to about 3300 g/m2 in the northeast Inner Mongolia, and the coefficient of variation for primary production is highest near the margins of the deserts in the west where rainfall is erratic. Though the high inter-annual variability in primary production undermines the identification of significant trends, we could not isolate any general decline in grassland primary production.

Despite a rapid increase in grazing animals on the steppes of the Inner Mongolia for the 1982–2006 periods, our space-based estimates do not indicate declining biological production. Although the cultivated land area constitutes only a small proportion of the total land area of the Inner Mongolia region, the findings of the primary productivity trends may be influenced by the increasing productivity of agricultural land. Other important factors contributing are the regional pattern of increasing precipitation over the 25-year period, as well as the *Green Wall* afforestation project and other vegetation cover improvement activities (Zhou et al, 2003). The high inter-annual variability in primary production for this region makes it however difficult to identify long-term trends, despite the 25-year length of our record.

New pests and diseases are emerging in the region, likely related to the warming. Poplar bark beetles are spreading rapidly in many oasis in Alxa and causing at least 30% of mortality of *Populus hopeiensis*, an introduced tree species that are widely planted as shelterbelt woodland in a way of monoculture. The spreading of poplar bark beetles is very likely a consequence of climate warming, as the geographic distribution of this species was formerly reported at lower altitudes and latitudes. Monoculture is another key factor causing the wide spread and high mortality of *Populus hopeiensis*. We found that almost all the death are happened in monoculture stands, whereas many poplar trees and other tree species survived at stands with cross-planted multiple tree species such as *Ulmus spp., Ziziphus spp.,* etc. We were told by local officials that several new livestock diseases were emerging too, but we could not find literature to confirm this.

4.2.4 Decadal changes of land cover

From early 1980 to 2001, the area of steppe/desert in Alxa reduced by approximately by 11.3%. After decades of heavy grazing and other human impacts, more than 90% of the grassland in Alxa suffered from degradation. The productivity of grassland was reduced by 25.3% in past 20 years. In 2003 a grazing ban policy was applied in the region. Since then, about 20% of the grassland in project area has been closed throughout the year and another 30% with rotation or seasonal grazing. There is a clear evidence of grassland recovery during our recent (late May 2008) field trip along Helan mountain piedmont area. However, in many sites of enclosed rangeland regeneration of shrubs and perennials are quite limited with litter and dry grasses accumulate due to absence of harvest (grazing) and slow decomposition of dead plant materials (Figure 4.5).

Figure 4.5: Enclosed rangeland under the policy of grazing ban since 2003

Meanwhile, Livestock feed prices have increased substantially since the grazing ban. Alfalfa reached ¥700/ton and corn straw priced at ¥260-280/ton. Feeding costs for sheep are reported to be ¥1.00-1.50/ day/sheep, and for cattle is ¥6-9/day/cattle. Thus, livestock production yields poor profit margins especially for small holders. This posts short-term difficulties for those small holders, even with government subsides, but it may encourage alternative livelihood and eventually release direct pressure on the fragile grassland.

As mentioned before, agriculture in project area deeply relies on irrigation, and irrigated cropland is mainly distributed in river valleys and oasis between sand dunes and the Helan Mountain piedmont. Most rain fed land that was cultivated previously is now left fallow and has been abandoned, along with “ghost town” villages (Figure 4.6). People have moved to new countryside villages with government subsides of housing, irrigated croplands, and basic facilities. By 2005 there were 320,000 ha irrigated cropland in Alxa, concentrated in several oasis such as Luanjingtan, Yaobatan, etc. As large portion of degraded rangeland in the region were closed under grazing ban policy, irrigated agriculture in the oasis become an important alternative livelihood for former herdsmen.

Figure 4.6: Abandoned villages and farmland are a common phenomena in severely degraded areas. Left: satellite image, right: ground photo by Gensuo Jia

The area of irrigated cropland increased by 166%, from early 1950s to 2005. The total area has been stabilized in recent year. However, behind the numbers there is a trend of loss of fertile cropland to rapidly expanded sandy desert along marginal land and continuous converting oasis vegetation and even vulnerable grassland and semi-desert areas into cropland. About 21.8% of oases were rapidly occupied by new croplands and villages in past decade. Meanwhile, large area of oasis along the Yellow River and Heihe River was converted into cropland in past 5-10 years, especially in south of the Bayanhaote. Further expansion of agriculture and "new countryside" villages in the western side of the Helan Mountain where rangeland is already threatened by desertification is under consideration. Despite of all the efforts made by governments and private sectors, there is no much room to expand irrigated cropland, largely limited by water availability.

As agriculture production increases, the efficiency in using irrigating water and fertilizer is still very low. The traditional crop varieties still dominate the croplands, although more drought/pest resistant varieties of corn, wheat, and other crops are already developed for years. Water waste in irrigation is enormous with traditional open surface irrigation and free water use. Water-saving technologies such as pipeline irrigation and irrigation on demand work well in several experimental sites, but their application is not well accepted among farmers. The grain production per cubic meter irrigation is only 0.85 kilogram, the irrigation efficiency is 0.44, or 80% of the national level. The use of fertilizer increased from 178.2 kg/ha in 1970 to 1950 kg/ha in 2002, but the efficiency is still very low. For example, the efficiency for nitrogen fertilizer is 30% compared to the national level of 40%. This is mainly caused by improper N:P:K ratio, which is 86.6:12.7:0.7 in 2002. Proportion of organic fertilizer mainly from livestock manure has sharply declined since the grazing ban, forced farmers spend more on inorganic fertilizer and get worsen soil texture.

On the plains of eastern Alxa, desert-steppe-based animal husbandry was gradually replaced by mixed agriculture with irrigated farming and animal grazing. This led to a great increase in land productivity, but also caused serious damage to grasslands and shrub lands. From the late 14th century to the middle of the 20th century, the growing population was exerting increasing pressure on the available land resources. As a result, land degradation began accelerating and environmental degradation became more severe.

From the early 1950s to the late 1970s, major farmland reclamation schemes were conducted to solve the food shortage problem. The area affected by land degradation expanded. Since the

1980s, economic development and construction have been greatly promoted to meet the demands of a growing population. However, the relationship between economic development and environmental protection was not handled very carefully. While efforts where made to promote the development of the local economy and to improve the people's living conditions, natural resources were over-exploited. Overgrazing, relentless farmland reclamation, indiscriminate firewood collection and herbal medicine digging have occurred. These improper activities have often resulted in the destruction of natural resources.

4.2.5 Policy analysis and Adaptation

The simplest solution to the overgrazing problem is to reduce the number of livestock in the overgrazed areas (Peters et al, 2006). However, with the high economic and population pressures in west Inner Mongolia, this solution is impractical. Our analysis suggests that careful spatial planning of domestic livestock numbers and densities according to the calculated carrying capacity is needed. It appeared that some areas still have stocking rate far below the carrying capacity of local steppe (Alxa League Planning Commission, 2007; Christensen et al, 2004), indicating potential for livestock expansion. Meanwhile, increasing the carrying capacity by improved pastoral management is needed. Livestock carrying capacity might be increased by increasing livestock mobility, by improving grass quality with cultivated pastures, and by using agricultural by-products.

Under the “urbanization and new countryside” strategy the city of Bayanhot urban area has been expanding rapidly in recent years. With the development of the Jilantai Town, Luanjingtan Town, and several large scale “new countryside” villages in Alxa Azuo Banner Figure 4.7, once remotely lived herdsmen are quickly moved to the remaining oasis with government support of housing and agricultural facilities. These policies have greatly released land use pressure on vulnerable desert steppe and desert, and helped ecological restoration of degraded rangeland. If planned carefully the towns could provide great opportunity for alternative livelihood of rural poor and therefore release direct pressure on marginal land. However, conversion of oasis into concrete and farmlands will have major long term consequences, as oasis ecosystems serve as very important regulator for regional climate and hydrology (Sullivan and Rohde, 2002)).

Figure 4.7: Ecological emigration and new countryside project

Another urban ecosystem related process in project area is so-called "new countryside development" project. With small subsides from government, farmers and herdsmen who live in isolated areas are encouraged to move to nearby main towns (Alxa League Planning Commission, 2007b). This may cause some social and environmental problems, but it is very helpful for improving infrastructure and releasing environmental pressure on land.

Besides, religion beliefs and local knowledge seem very effective for vegetation protection in the region. Xiemenke Bayer is a Mongolian herdsman who lives in an isolated small village, Wulanquanji located in the Ulan Buh Desert. His family have been there for centuries since his grandfather moved in 90 years ago. He is a secondary school graduate, but he is always proud of his half-year training experience on land management in Beijing about ten years ago. He told us that he and his neighbours found several hectares of a "holly trees" in the desert about 20 years ago and decided to protect them since then. They believed that these trees are unknown anywhere else and are God's bless to his village. They were surprised by the strong survival ability of the tree despite of decades of severe desertification, therefore believed they can protect the village and the residents as long as they are there. With his guide we located the trees sparsely distributed among sand dunes. Roots were eroded by wind for many trees, but they all grown well. After a quick taxonomy check, we recognized that they are *Rhamnus erythroxylon,* a common small tree species distributed in northwest China (Zhao, 2007). However, the religion believes of the villagers greatly helped the protection of the woodland (Figure 4.8), and therefore land itself.

Figure 4.8: Sparse woodland at the edge of Tengger Desert

4.2.6 Summary, problems and recommendation

The above investigation and analysis show that there are four main causes for the land degradation process. They are:

1) Harsh natural conditions: Precipitation in the arid and semi-arid region is limited and the ecosystem is fragile. The amount of rainfall varies remarkably between seasons and from year to year; droughts and sandstorms are frequent. Due to the dry ground surface and low vegetation coverage, the sandy soils are very sensitive to wind erosion if vegetation is removed;

2) Over-utilization of natural resources: Reclamation of marginal land, indiscriminate firewood collection, digging of medical plants, extensive farming, and poorly planned irrigation are causes of desertification in the region. Farmers tend to reclaim sandy grassland for growing crops in years of high rainfall, and then abandon the land in years of low rainfall. This temporary cropland is so-called "try-chance farmland";

3) Overgrazing: Natural rangeland covers 100,000 km2 in Alxa. The reasonable grazing supporting capacity is estimated to be 160,000 sheep units. Before the grazing ban, there were more than 240,000 domestic animals grazing on this grassland, much more than it can support;

4) Improper land restoration practices: many land restoration practices have focused on planting trees in this arid region, and also tried to flatten sand dunes for cultivation. There is also wide confusion between natural sandy land and desertification.

Overgrazing itself is still conspicuous and traces are evident on the lower slopes of Helan Mountain and on the alluvial fans. It is obvious that this uncontrolled grazing, mainly by goats, severely damages the natural vegetation (Evans and Geerken, 2004). However, even in heavily overgrazed areas annual grass and grazing resistant shrubs vegetation still survived. This is evidence that with appropriate protection a reasonable vegetation cover could regenerate in the areas. The fact that natural shrubs, *Caragana stenophylla*, wild Chinese date (*Ziziphus jujuba*) and grey elm, exist in the alluvial fans and in other desert parts proves the adaptability of the respective cultivated forms for ecological restoration of degraded the dryland. Plants adapted to semi-arid regions (desert-steppe – the most arid type of grassland) characterize the vegetation in the project area. Cultivated plants include ash trees, apples, pears, apricots, wild Chinese dates, willow, juniper, ailanthus, alfalfa, Sudan grass and other grasses.

So, overgrazing vs. lack of grazing? The total grazing ban started in Helan Mountain Nature Reserve in 1999. As a nature reserve, land there was never leased to local herdsmen; therefore, it was relatively easy for the authority to exclude livestock from desert steppe. Since the remove of the 200,000 livestock used to graze within the nature reserve, vegetation recovered fairly fast. However, new problems emerged as dry grass and litter accumulate due to lack of grazing and low decomposition rate. Many dominant shrub species such as *Reaumuria soongorica* can not regenerate and decline significantly, meanwhile, wildfire becomes more frequent and intensified. Goats and camels are main livestock species, followed by sheep and horses. Over the past 20 years goats gradually gained absolute dominance over camel, largely driven by the market. Both cashmere and lamb of goats have favourable market prices that are still rising. The grazing of goat are much more destructive to rangeland because of their grazing habits and food structure, therefore, increase of goat population is a major contributor to rangeland degradation in Alxa, even without increase of stocking rate. Camel has been native livestock in Alxa for centuries and plays a symbolic role on the landscape (Figure 4.9). It well adapts to the arid environment as an integrated part of the ecosystem. Therefore, keeping a reasonable camel population is critical for Alxa. Fortunately, a non government organization named the Alxa Association of Camel Protection was established in 2007 to work on stabilizing camel population before it is too late.

Figure 4.9: Camels are symbolic livestock in Alxa

Soil salinization is also a serious environmental problem in Alxa that affects human living, irrigation, and ecosystem productivities. Major reasons for soil salinity in project area: 1) Shortage of irrigation water favors salt/alkaline accumulation; 2) poor maintenance of wells and electrical drainage stations throughout the area. For example, only 1/8 of the drainage pipelines are functioned well, most of the drainage wells were abandoned, and only 1/3 of electrical drainage stations operate.

Recommended solutions: ground-water irrigation area apply water-saving irrigation technologies, improve leaking control. Yellow River water irrigation area – repair and improve the functions of drainage canals, wells and pumping stations, adjust water price and water use right.

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4.3 Water resource management and institutional adaptation

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Inner Mongolia is one of water shortage provinces in China. Its total water resources is about 50.9 billion cubic meters, 1.86% of the state total of China, with a personal amount 2281 cubic meters, 86% of the state average (Development plan for water resources of Inner Mongolia, 2005). Hence to properly exploit, allocate, employ and protect water resources always is one of the top issues in the Ninth, the Tenth and the Eleventh Development Plans of Inner Mongolia autonomous region. The shortage of water resources is especially an essential problem in Alxa League, an extreme arid region. The total amount of water resources for the league is about 1883 million cubic meters (not include three large deserts there), but only 47% is available, of which ground water and surface water are respectively 55% and 45% of the available water resources (Li, 2001). The average amount of water resources per capita is only 110 m^3 (4.6% of the national average). Climate warming has aggravated the scarcity of water resources in Alxa League because the surface evaporation is intensified with increasing temperature. Residents and livestock are still suffering from a shortage of drinking water, and irrigated agriculture is facing great challenge of ground water table drop and decline of river water availability.

4.3.1 Water use and water scarcity

The water scarcity can be identified by the most stakeholders we visited in field survey, in-depth interview and stakeholder workshop. The statistics from 2008 field survey questionnaires in Azou Banner of Alxa League demonstrates that 74% of the 49 respondents felt the water resources have decreased or significantly decreased since 1980s (Dai et al, 2008). The respondents include 32 males and 17 females, 11 Mongolians and 38 Hans, work in agriculture, livestock, scientific research, administration with different education levels from graduate, undergraduate to almost no education.

Although water resources are very limited, water waste is a serious problem in Alxa due to poor irrigation systems, over-irrigation, open channel evaporation and seepage in irrigation channels. Based on our survey data, the amount irrigation water used is estimated at 9,200 m^3/ha, but the water-use efficiency is estimated at only 40%. For the production of 1 kg of cereal grain, 2.5 cubic meters of water are consumed - over twice the national average of China. In some places over-irrigation has caused the drop of groundwater table, further inducing secondary soil salinity from ground water.

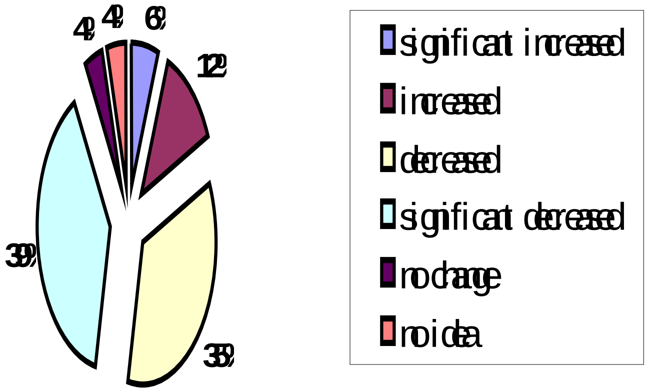

Figure 4.10: Change in water resource from questionnaire statistics in 2008 (Dai, 2008, 2009)

Due to the higher salt concentration, the ground water in Alxa is becoming less suited for drinking and even irrigation than water from the rivers flowing through the region. 90% of the ground water abstracted for domestic and industrial purposes on the Alxa Plateau is drawn from the deeper aquifers and only 10% from the shallow ground water. Many locations in the project area suffer from over exploitation of ground water and infiltration of salt lakes. This causes the drop of the groundwater table and causes problems as groundwater receives high salt content.

The most critical environmental factor in Alxa is water availability. On this harsh land water resource can only support limited vegetation cover, including natural and planted. Increased irrigation of crop and shelter belts (poplar) have greatly enhanced water shortage and caused overexploitation of groundwater. In many areas ground water table has dropped from 25-30 meters in 1970s to present 120 meters. Only 10% of irrigation facilities use water-saving techniques such as plastic pipeline.

In Brunbieli and surrounding areas, the drop of ground water level, penetration of salt lake water, bad water quality are critical problems for water use efficiency and local development. In the past 20 years average ground water table has dropped from less than 30 meters to approximately 120 meters, due to combination of increase of evaporation and irrigation from ground water as croplands continuously expanded. As ground water level drops salt lake water penetrates underground and increases salinity of ground water. Nowadays ground water is no longer suitable for drinking in many areas, but still acceptable for irrigation. However, the situation could get worse if water table continues to drop.

Meanwhile, competition of water use by tree plantations, especially by introduced species with high water demands is another important factor for degradation of oasis ecosystems and shortage of irrigation water availability. To make the situation worse, competition of water demands from rapid growth of chemical and energy industries, urban expansion, and related gardening is likely to get serious in coming years as local governments are trying hard to boost industrialization with high water demand factories in this arid region with scarce water supply.

In summary, the key ecological limiting factor in the region is water. Lack of water resources, continuous drop of ground water levels, and degradation of ground water quality due to penetration of salt lake water are serious problems related to water resources in this arid region. Further climate warming will likely enhance the potential of evaporation, and therefore widen the gap between demand and availability of water resources and continue to deteriorate water quality. On the other hand, the western part of Alxa had been suffered from water use conflict between different reaches of Heihe River in the past hundreds years.

4.3.2 Heihe River water reallocation

Heihe River is the second largest inland river in northwest China, originated from Qilian Mountain in the south of Qinghai province, stretching over a basin of 821 km across three provinces, i.e. Qinhai, Gansu and western Inner Mongolia. Its mid-reach fcrosses Zhangye region of Gansu province, and. its lower reach, referred is named as Ejina River, is divided into West River and East River (Figure 4.11). The two branches of the Ejina River are of 220km long in Ejina Banner and finally end in West Juyan Lake and East Juyan Lake, respectively (Yang, 2002). The Ejina oasis, located along the bank of the east river, was one of the biggest oases in northwest China that serves as the natural ecological barrier for Alxa and has a decisive function for protecting local environment.

The Ejina River is a seasonal inland river. It has a determinative function for the maintenance of the Ejina oasis where a lot of relics are remained, for example the Heicheng, an ancient city in Xixia dynasty (881-1227 A.D.). This demonstrates that there had been a very good ecological state in Juyan oasis during the history time. A text caved on a stele at the Juyan lakeshore describes the flourishing vegetation around the lake back then.

Figure 4.11: Heihe River (left) and Yellow River

However, since 1950s, more and more people migrated onto the mid-reach of Heihe River owing to good irrigation agriculture depending on relatively stable runoff of Heihe River every year. The local population in the beginning of twenty first century increased by 2.29 times to 1950s, and meanwhile the farmland area was also expended by $18.6*10^4$ hm^2 from $9.7*10^4$ hm^2 (square hundred metres) in 1950s (Chang et al., 2005). Hence, more and more water was introduced from Heihe River to irrigate the farmland with the construction of tens of large & middle sized reservoirs. The water usage even reached 93% of the runoff in the mid-reach (Yang, 2002). In consequence the water flowing into Ejina area was reduced significantly. As a result the West

Juyan Lake was dry up in 1961 and the East Juyan Lake was dry up completely in 1992. Two of our respondents told us that the Juyan Lakes became desert and Salina cover from the first time visited them by camels in middle 1960s and 2002, respectively.

As ground water table declines, large areas of Euphrate poplar (*Populus euphratica Oliv.*) forest and tamarix (*Tamarix austromongolica*) died in the oasis. It resulted in the expansion of desert and degradation of oasis. Since 1980s, the degradation of oasis vegetation has been accelerated along with rapid loss of biological diversity due to general privatization policy issued in China. The area of oasis has been reduced from 6,500 km^2 to 3,328 km^2 in the period (Lu et al. 2002). Remotely sensed studies (Wang et al. 2001) demonstrated that the Ejina oasis has experienced rapidly degradation of ecosystems and declining of area from 1986 to 2000. The areas of lakes on northern and eastern Ejina are distinctly reduced. Area of the oasis is rapidly shrunk from 1986 to 2000, with a total reduction of 61.48%, or reduction rate 4.39% annually. One of the consequences is that it supplies more sand sources for sandstorm formation from Ejina Banner. The first severe sand storm was observed in spring 1993, mainly from dried bed of Juyan Lake and Heihe River Valley.

4.3.3 Conflicts and adaptation

The Heihe River water-use conflicts had experienced a long history due to large-scale agriculture development in its basin. The oldest reallocation called 'Jun Shui Zhi', which means uniform water redistribution along the river, issued in 1726, by Genyao Nian, a military commander of Qing Dynasty (1644-1911, AD) for solving the water-use conflicts along Heihe River (Yun, 2007). In Jun Shui Zhi any water-taking from the upper and a section of mid-reach of Heihe River was forbidden during the ten days just before the solar term 'grain in ear' (5^{th} /6^{th}, June) so as to support crop seeding in up stream of the lower reaches. Since that time the 'Jun Shui Zhi' had been kept as a regulation for Heihe River users until 1950s when the river water use increased rapidly resulting from large-scale farmland cultivation and migration in mid-reach of the river. The runoff for the lower reaches became much less abundant, which caused degradation of Ejina oasis and drying-up of West Juyan Lake in1962. This reveals that the 'Jun Shui Zhi' is no longer suitable to the river basin with climate change and economic growth. This situation makes the development of a new water reallocation regulation for whole Heihe River basin became more and more urgent.

The first official regulation (Shuigui[1992]41hao, 1992) on water reallocation of Heihe River was issued in 1992 (hereafter R92) by the Ministry of Water Resources of China. 40% and 60% of the amount of the water flowing into the mid- reach was allocated to the mid- and lower reaches, respectively, under the consideration of the water usage that meets proper farmland expansion in mid-reach and the requirements on ecological water use , stock herding and small scale farming in lower reaches. In addition, the R92 emphasizes the importance of protecting forest and surface vegetation and the pollution problems to local water resources for the up reach, the importance of developing water-saving irrigation techniques and enhancing water use efficiency for the mid-reach, and the importance of protecting ecosystem against desertification and land degradation, and reducing the water loss during water transportation in water channels. R92 also suggests constructing a series of hydrological engineering along Heihe River basin in order to guarantee the reallocation tasks in R92. Besides, institutional issues are raised on how to coordinate and implement the water reallocation scheme over the three provinces. It seems that an inter-provincial institution should be set to monitor and manage the implementation of Heihe river reallocation project.

The arguments and conflicts were still remained among the three provinces since the R92 was released due to lack of detail terms of policies, measures and instruments confronting various problems encountered in performing the regulation. This is especially due to the lack of an inter-provincial coordination institution and monitoring mechanism. There are a number of serious problems involving the water reallocation in the basin. The first is unreasonable water allocation to other uses in the Heihe River basin. Strong sunshine and rare precipitation provokes huge surface evaporation, which caused many economic problems within the provinces and serious conflicts across the provinces. Secondly, there was lack of systematic planning in hydrological infrastructures along Heihe River. For instance, too many reservoirs were built in mid-reach with many sub-channels for cropland irrigation. The major problem in the lower reach is low water use efficiency due to poor irrigation facilities and techniques. The third is water leakage during transportation through open water channels that open to sky over extremely dry Ejina plane. The forth is lack of water transfer adjustment dams over the lower reaches of the river by which the runoff could be effectively distributed to meet local farming and other requirements. Fifth, insufficient founding is a key problem in agriculture development and construction of irrigation facilities and hydro-engineering due to poor economic level of west Inner Mongolia. The last one involves the water resources management. For instance, there was no cross-provincial institution or agency to monitor and manage the water reallocation implementation and lack of corresponding administrative, economic and legal instruments that support the regulation. It seems that administrative regulations may not be an effective way in solving the water-use conflicts among the provinces. Practices manifest the necessity to make amendment to the R92.

The second regulation (Shuizhengzi [1997] 496hao, 1997) about how to share Heihe River water among the three prvinces was issued by the Ministry of Water Resources of China in 1997 (hereafter R97) in the bases of further investigation and careful planning since 1992. the R97 is an updated version of the R92 with more detailed descriptions on social and economic conditions and natural resources in Heihe River basin and detailed reallocation tables that contain when and how much the water amount should be released in consecutive dams on the River. In order to carry out the tasks in R97 before 2000 four measures are described as 1) to establish Heihe River management bureau and explore the effective management mechanisms, 2) to manage the river by use of corresponding lows that should be made under the direction of related national lows and regulations, 3) to control the amount of water use in mid-reach, i.e., to control the cropland area and use water-saving strategies in irrigation and industry, 4) to manage the water use by economic way, in which new water prices (/m^3) were made depending on the water amount and purpose of water usage. A careful planning for implementing R97 was made jointly after 1997 by several institutions on different levels for optimal operation of the regulation R97.

In 2001 the State Council of People's Republic of China finally authorized the Planning of Heihe River Governance (PHRG), noted as Guohan [2001] 86hao. There some new terms in PHRG in addition to R92 and R97 with regard to regional sustainable development, such as to enforce adjustment in economic structure under sufficient consideration of local water resources, to control irrigation cropland and make conversion of farmland of 320,000 mu to grassland or forest by the end of 2003. Additionally other measures included the change of crop varieties and confine water-consumed crops such as rice and to restrict intensive water-consuming crops with heavy pollution. Moreover, it indicated the importance on how to coordinate the institutions in different levels and sectors pertaining to governance of the regulation R97 with democratic strategy for the river basin. Besides, economic mechanism is emphasized again in terms of water price, because the water price is concerned by all water users and therefore is the joint point of all activities in different levels and locations.

4.3.4 Water reallocation implementation

The R97 implementation has achieved many positives goals. In spring 2000, central government of China made an important direction about ecological protection and construction of Ejina Oasis basin on R92 and R97. Ministry of water resources fulfilled the direction of the premier and set up Heihe watershed management bureau in Lanzhou, capital city of Gansu province, to take charge of the water reallocation. In 2000, it is the first time to realize the uniform water reallocation for water resources in Heihe watershed historically and successfully assign water to lower reaches of Heihe River. This way, it provides water resources to protect eco-system in Ejina Banner.

Recently, correlative national and regional governments have carried out a series of measures about water reallocation under the lead of Heihe watershed management bureau. In mid-reach region, the reallocation of water resources in favour of lower reaches has been implemented 19 times in past two decades. The draining volume in Zhengyi Gorge where a key dam exists reached $54.75\times10^8m^3$, average annual draining amount is $9.125\times10^8m^3$, which increased $1.44\times10^8m^3$ compared with $7.69\times10^8m^3$ before the water reallocation in 1990s. The water amount from Langxin mountain dam to Ejina is $26.185\times10^8m^3$, with average annual amount is $4.36\times10^8m^3$, which increased $0.59\times10^8m^3$ compared with $3.77\times10^8m^3$ before the water reallocation in 1990s. Since July 2002 the river water has been transported ten times to East Juyan lake, the maximum Juyan lake area reached up to $40km^2$ in October 2008 and accumulated water amount to lake is $1.58\times10^8m^3$ (Lu, et al. 2006). The Juyan Lake has kept its water all year for four years by the end of 2008 since the first water flow arrived in the lake in 2003. The lake eco-system has been gradually regenerating since 2004 (Figure 4.12). Two beautiful reeds emerge and fishes, shrimps, crabs and turtles appear again in the lake since the lake dried up in 1992 (Dai and Liu, 2006).

Figure 4.12: Juyan Lake (Photo: Dai, 2006)

The successful realization of the water reallocation scheme has led to a significant regeneration in surface vegetation over lower reaches of Heihe River basin. Satellite remote sensing study shows that the bare land during 1996-2002 had been expanding with shrinkage of sparse, media- and dense vegetations over Ejina Banner (Figure 4.25). The water reallocation project began in 2000 because of insufficient water that flowed into the lower reaches and poor water resources facilities and poor hydro-engineering on the river (Guo et al, 2002). However, the reappearance of East Juyan Lake since 2003 has an obvious function to renew the vegetation of Ejina oasis around river, but have no obvious efficacy to the vegetation growth away from the river (Guo et al, 2004, Duo et al, 2008).

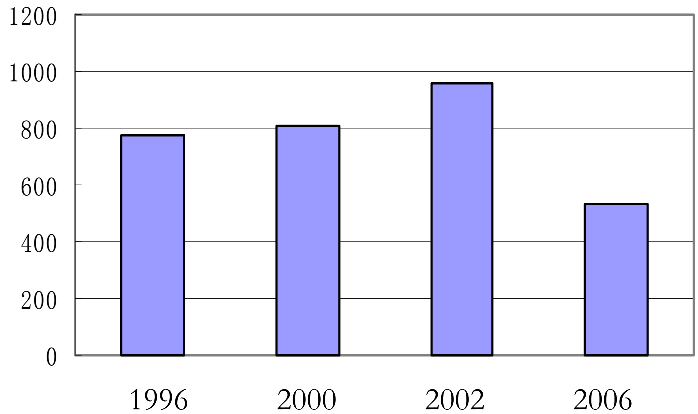

Figure 4.13: Evolution of bare land in Ejina Banner from remote sensing (Duo et al, 2008)

Owing to new institutional setting and implementation of new measures under the water reallocation plan the bare land had reduced from 960.88 km^2 in 2002 to 533.14 km^2 in 2006, whereas the areas of sparse, media- and dense vegetations had expended from 87.71 km^2, 0.52 km^{2}and 0.0 km^2 in 2002 to 214.96 km^2, 25.82 km^{2}and 0.005 km^2 in 2006, respectively. The latest news reports that the accumulation of water that flows into the Ejina Banner is up to 4.6 billion cubic meters since 2000, and the Gobi and sandy land has reduced 39 km^2, while the grassland and shrubs increased about 40 km^2. The Euphrasian Poplars (a special local specie with three different forms of leaves in a same tree) increased from 390,000 to 440,000 mu with expanding vegetation cover rate 25% under the Poplar trees (Figure 4.14). The regeneration of the surface vegetation in Ejina oasis has tempered the physical bases of sandstorm occurrence, and the meteorological observation demonstrates that the sandstorm occurrence had declined from 19 times/per year in 2000 to 10 times/ per year in 2008.

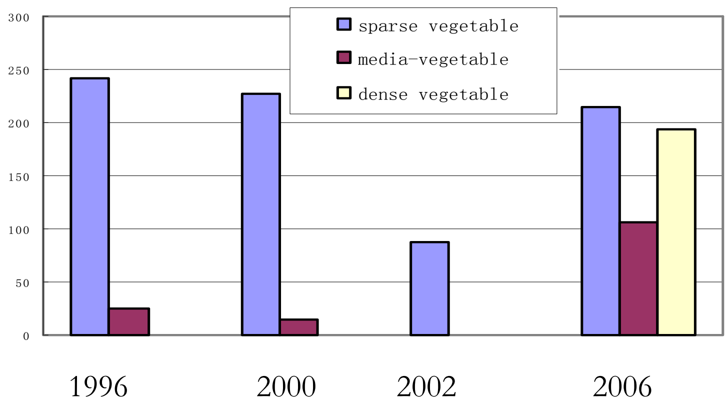

Figure 4.14: Evolution of vegetation covers in Ejina Banner from remote sensing (Duo et al, 2008)

4.3.5 Policy assessment

Water-saving and water facility improvement are two major strategies against the shortage of water resources at local level in Alxa. There was a field survey with 132 respondents from Inner Mongolia (Dai, 2009), including 2 farmers, 3 herdsmen, 8 in enterprise, 62 in government, 24 in meteorological bureau, 27 students, 5 in service, 1 teacher, of which 76 are male and 56 are female. As for the effect of water facility construction 60% election rate of the 132 respondents select distinct or very distinct terms, and only 6% of them select the term 'indistinct' (Figure 4.15). It demonstrates that the government investment on water facility construction has been being an effective measure on conservation of local water resources for past decades.

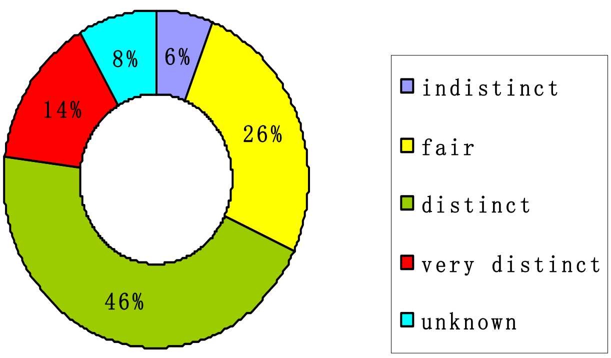

Figure 4.15: Survey on effect of water facility construction from 132 respondents, 2008

As for water-saving strategy, 62% election rate is on term 'distinct' or 'very distinct' (Figure 4.16). This reflects that the promoting water-saving technique or water-saving irrigation methods is successful in combating water resource scarcity.

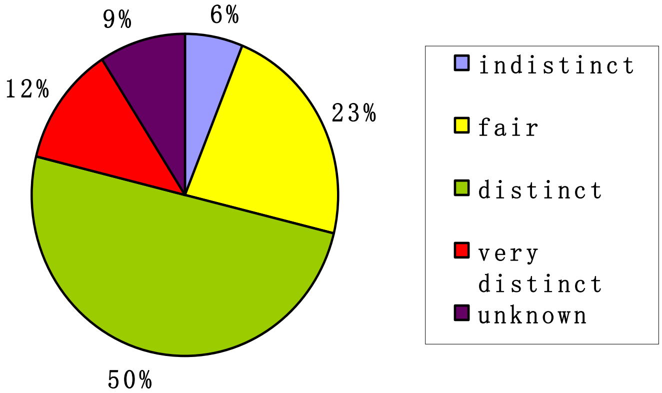

Figure 4.16: Survey on effect of water-saving strategy from 132 respondents, 2008

According to our in-depth interviews, some achievements have been reached in terms of R92 and R97, while somewhat problems still remains in implementing processes, such as the distempered regulation about water reallocation in Heihe River and difficulties in carrying out the national direction goals. For example, in the process of water reallocation the mid-reaches owe the lower reached 3.05 hundred million cubic meters during 2003-2005 and 10 million m^3 in 2006. In addition the respondents we visited in water management offices of Ejina and Bayanhot complained about the uniform water reallocation periods, some of which did not open their water gates in the season they need water very much. Meanwhile, correlative regional governments are not unanimous in the scheme, and it needs a further adjustment by national government. One director of the water management offices emphasized the importance of water use legislation for whole Heihe River basin with detail terms on the reallocation and punishments if the reallocation scheme was not followed. Additionally, the stakeholders raised the water right issues and demand conserving their water rights. The conservation water rights need to uniformly control and coordinate the water use over both countryside and city. This entails coordination of upstream and mid- and lower streams of Heihe River, by the corresponding institutions for management and monitoring of the river water reallocation practice.

Water saving is one of important adaptation measures confronting water resource shortage. Zhangye is the largest city in mid-reach of Heihe River, and suffering from water shortage due to rapid economic development and the reallocation constraints. How to save water has become an important challenge for local government. The first measure is to reduce intensive water-consuming industry and crop extension, for example. Zhangye has limited the rice plantation,and had reduced ten thousand mu of rice plantation in three years. The second is to plant new varieties that need less irrigation water. The farming experiment in Yaoba, a township in Alxa, shows the millet (*Setaria italica*) irrigation amount is only one-third of maize, but with higher production and market price (SEE Project). The third is to construct hydro-engineering so as to reduce the loss in water transportation resulting from channel leakage and evaporation. The market instruments are also used to constrain amount of water use. The fourth is to make new water prices depending on different purposes of water usage in order to control water use amount. The following table lists a part of water prices for Inner Mongolia (Bureau of water resources of Inner Mongolia, 1997).

Table 4.1: Water price for different use in Inner Mongolia

Water use purpose	Price Chinese yuan/ m^3
Residents or living	0.3
Administrative	0.4
Industry	0.4
Business and restaurant	1.0
Tour and public bathhouse	3.0
Civil construction	1.3
Urban greening	0.1
Farmland irrigation	0.02

The motivation of such water use prices is obviously in favour of agriculture development and urban greening, and to constrain the water use in business, restaurant, tour, public bathhouse and civil construction. Moreover, a new regulation issued in 2008, with various limitations and thresholds about water price and water amount for both surface and ground water. Water-taking permission must be applied before using water and additional fee is requested to pay if water use amount exceeds the thresholds in the regulation.

In addition a series of adaptation measures and administrative regulations that are matching are being issued to coordinate the different sectors on water use. Different grazing strategies were set for different parts of Ejina River basin according to water availability and landscape. The rotational grazing, limited grazing and grazing ban are applied respectively in up, mid- and lower reaches of Ejina River. Correspondingly migration (Figure 4.17) and herb-plantation are also carrying out in the banner.

By the end of 2008 the Heihe water reallocation efforts have effectively increased water availability in Juyan Lake and Ejina River, which has raised ground water table and increased vegetation cover, and therefore reduced dust and sand exposed on dry lake/river beds. By all appearances Heihe River reallocation is a successful case on how to coordinate the water users in different sectors and make reallocation in different reaches of a river in context of climate change. Nevertheless, our field survey shows that some of local stakeholders had not yet understand the adaptation measures, for example they asked why the officers let the water freely evaporating in Juyan Lake in stead of farmland irrigation. It seems that social learning, especially climate learning is necessary in implementation of climate change adaptation and mitigation for local stakeholders.

Figure 4.17: Ejina immigrant village (left) and cotton fields near by Ejina River

Migration is one of the most important strategies in connection with the reallocation of Heihe River water. An emigrant village was constructed near by Ejina town since grazing ban. The emigrants were given compensation for their trees, grassland in home land when migrated to the village, but they worried about their future once the migration project end, because most of their compensations and insurances are supplied by one or two projects including medical care, children education and social insurance. So, sustainable adaptation strategy on migration should be mainstreaming into policy–making processes at different levels. A unique migration policy for whole three banners in Alxa League is strongly requested by local immigrants.

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4.4 Impacts on agriculture, risk and adaptation

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Climate change and extreme weather events are resulting in various impacts on agriculture production in Alxa League (Bai, et al., 2009), Inner Mongolia, including shifts in the seeding season, crop diseases, an increase in climate-related hazards, water scarcity, ground water drop, salty water intrusion, etc. The main economic income of the farmers and herdsmen comes from animal feeding, food production and economic crops, which account for 99% of the total. Market demand and prices of crop and livestock products are the leading factors that influence their incomes. Drought and sandstorm are the main hazards, which greatly impact agricultural and livestock. Climate change will be significant for the agricultural sector, with rising trends in sandstorm occurrence and reducing trends in snowstorm in recent years of particular concern. Over the past 30 years, the crop structure in the region has changed, with an increase in the cultivation area of corn and sunflower, whilst there has been a decrease in wheat. These changes have mainly resulted from technology, market direction, governmental policies, and the impacts of climate change. A series of agriculture adaptation measures have been implemented to cope with climate change and environmental deterioration (Tenth and Eleventh Five-year Plans for Inner Mongolia). As part of the research programme, existing, and potential, adaptation responses have been analysed using a combination of field surveys, questionnaires, and stakeholder workshops to conduct integrated policy-appraisal exercises for the agricultural sector.

A numerical simulation of maize growth (conducted by means of a crop model) was used to investigate optimal irrigation strategies and the potential for water saving.

4.4.1 Impacts and hazards on agriculture

Climate-related hazards, and their potential impacts on agriculture, were estimated statistically from the questionnaires made in the project area. Furthermore, in order to formulate the adaptation strategies and better understand the impacts on crop production and livelihoods of farmers, a questionnaire survey was carried out in Alxa League in May 2008 involving 49 respondents (male/female: 32/17), including two farmers, three herdsmen, eight from enterprises, twenty four from meteorological bureau, twenty seven students, five from the service sector, and one teacher. The survey shows that these stakeholders have important local knowledge of climatic conditions and their experiences correlate closely with local meteorological observations. For instance, the results for climate change, precipitation decrease, increase in sandstorm intensity, increase in drought frequency are respectively 35 /49, 31/49, 27/49 and 23/49 in the questionnaires. Those climate hazards considered most important for local agricultural practice are drought, sandstorm and heat wave – results being 47/49, 40/49 and 24/49, respectively (Figure 4.18).

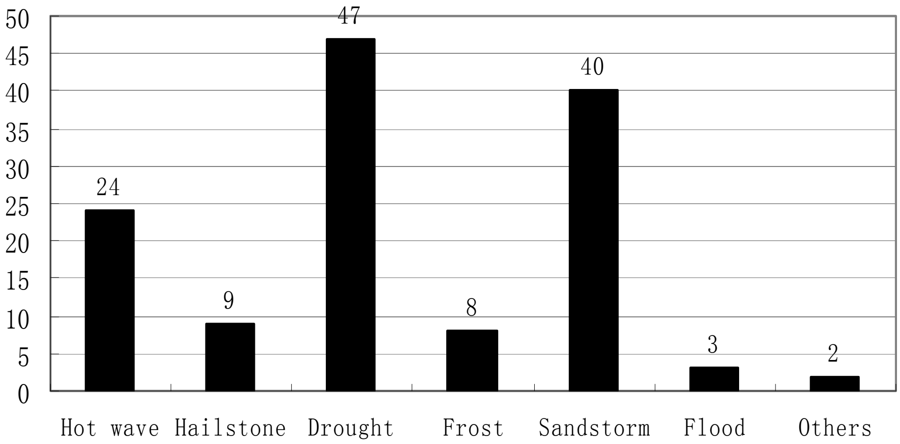


Figure 4.18: Responses from 49 stakeholders on agriculture hazards from the survey in Alxa League in May 2008.

A key finding from the interview process was confirmation of the northward shift of local crop cultivation although the questionnaires show that warming is only a slight impact on the northern edge position of local crop cultivation (respondent rate of 7/49). Furthermore, the crop growing seasons have been changing too. The survey also revealed that local crop types have increased with an increase in warming, and areas of grassland are seemingly recovered (after the grazing ban, especially), whilst livestock diseases have significantly increased due to the warming. In addition, the livelihoods of local residents have been affected by the drought, as evidenced by the 48/51 response rate agreeing that climate change influences are serious in agriculture, water resources, and living standards. Frequent drought has led to damage to crop production, with total losses occurring in the most severe droughts. Generally, about half of their livestock had to be killed in those years when extreme weather or climate events occur. Heat waves are one of most important climate-related hazards in Alxa, tending to occur about every three or five years, with serious implications for local crop and livestock productions and the living standards of local residents. Drought occurs almost every year, leading to negative impacta on agricultural production. However, there may also be opportunities for diversification in the region as the climate changes.

Local irrigated cropland has expanded by 166%, from the early 1950s to 2005, with the total area stabilizing in recent years. However, behind the numbers there is a trend of loss of fertile cropland with rapidly expanded sandy desert along marginal land and continuous converting oasis vegetation and even vulnerable grassland and semi-desert areas into cropland. About 21.8% of oases were rapidly occupied by new croplands and villages in the past decade. Meanwhile, large area of oases along the Yellow River have been converted into cropland in the past 5-10 years, especially in south of the Bayanhot. Further expansion of agriculture and "new countryside" villages in the western side of the Helan Mountain, where rangeland is already threatened by desertification, is under consideration. Despite of all the efforts made by governments and private sectors, there is little opportunity to expand irrigated cropland, largely limited by water availability.

4.4.2 Adaptation

Various measures such as drought-resistant crop varieties, plastic film mulching and ecological migration have been developed to adapt to climate change (warming and drying) in the region. The survey on preferences for responding to drought shows a 42/49 rate for plastic-film mulching technique, 39/49 for drought-resistant crop varieties, and 32/39 on ecological migration. Only a small group (8/49) chose the alternative livelihoods option (Figure 4.19), influenced by the fact that no one is permitted to graze in the areas for sustainable production of pastures.

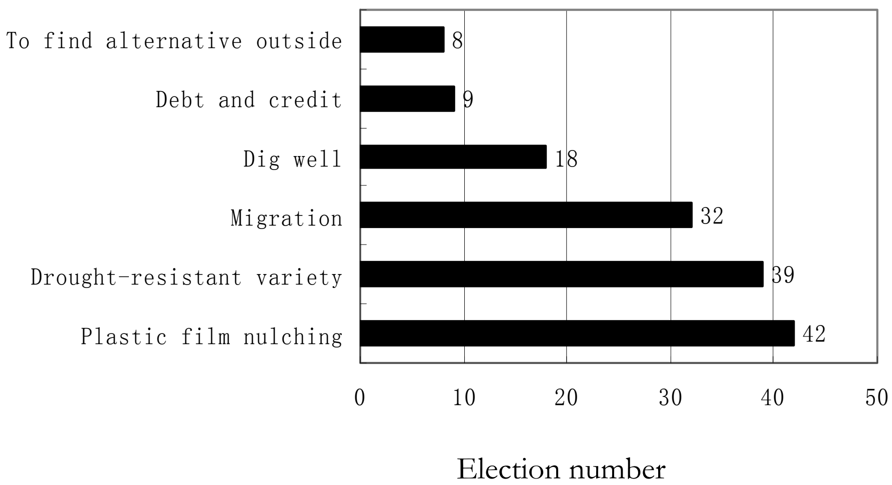


Figure 4.19: Response rates of 49 stakeholders on their preferences for techniques to respond to warm and dry climate conditions - from the survey in Alxa in May 2008.

Confronted with the natural hazards mentioned above, local people would, in general, also highlight other difficulties associated with funding, water availability, technology inputs, and infrastructure (Figure 4.20). To combat these issues, stakeholders often get help from their village committee, township office and the senior agencies of government, in the form of agricultural resource funding, financial capital, information on crop production, education and training on agriculture techniques, conservancy construction on farmland and water facilities, weather modification etc. This area of Inner Mongolia has adopted water-saving irrigation techniques and other water-saving measures, such as improving irrigation facilities and the selection of water-saving crop varieties. Nowadays, the area using water-saving irrigation is only a small proportion (24%) of the total irrigated area in Alxa League (Annual of Inner Mongolia, 2006). In order to adapt to climate change, crop plantations have adopted several measures like improved varieties, an increase in fertilizer use, and an updating of irrigation facilities for increasing food production. However, local farmers suggested that the introduction of new techniques only contributes to 10-20% of crop production.

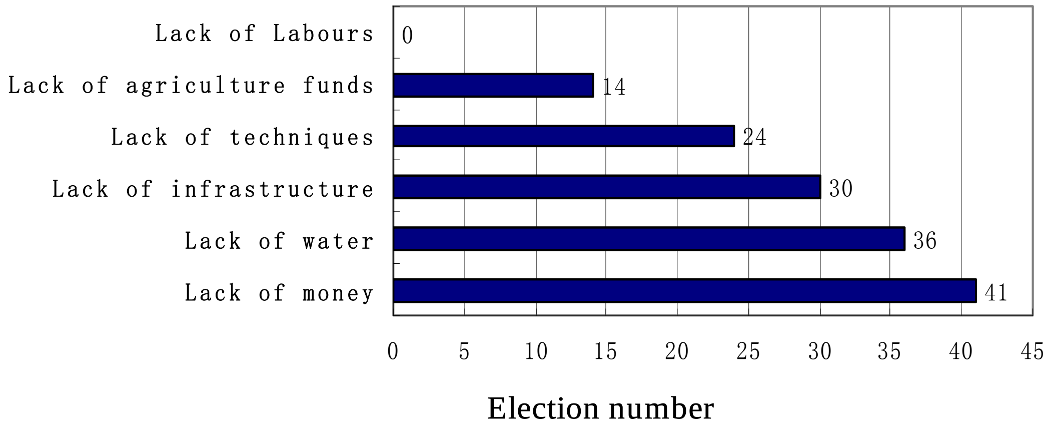


Figure 4.20: Response rates of 49 stakeholders on difficulties encountered in remedial measures against natural hazards from the survey in Alxa League in May 2008

Over the past 30 years, the farming and stock breeding population has changed significantly, with about 30% leaving their villages. Despite an increase in farmland, the areas of grassland, natural oases, and lakes has been decreasing with a changing climate over the past decades.

Soil degradation, with an increase in salt and alkali components, is a particular problem in Alxa region. Impacts have affected living standards, irrigation schemes, and overall ecosystem productivity. Major reasons for soil degradation in the project area are:

1) Shortage of irrigation water leading to excess salt/alkaline accumulation, and

2) Poor management of wells and electrical drainage stations throughout the area. For example, only one-eighth of the drainage pipelines operate efficiently and most of the drainage wells have been abandoned. In addition, only one-third of electrical drainage stations are in operation. More details of climate impacts and adaptation in the agricultural sector are now explored in the context of two local cases - Luanjingtan and Barunbieli townships.

4.4.3 Barunbieli case

Barunbieli, a township, lies in the southeast of Alax League, west of Helan Mountain, facing the Tengger Desert on its west side. Barunbieli is a food grain producing area in Alxa League developed since the early 1970s in which there is 80,000 *mu* (Chinese hectare, 1.0 *mu*=666.66 m^2) of sowing area, 310 supporting wells, and 150,000 livestock. The region is typical well-irrigated agriculture, perhaps the largest region of well-irrigated agriculture in Asia. Its production mode changed from the previous semi-agriculture and semi-animal husbandry to total agriculture. The main crops are maize, oil sunflower, wheat and purple melon. Nowadays, maize and sunflower are the major crops grown in the area.

4.4.3.1 Climate change impacts

The in-depth interviews of local stakeholders revealed that climate change has also significantly influenced Barunbieli development at the local scale. Drought has become the most serious problem affecting local farmers and herdsmen's production and their daily life. With decreasing levels of local precipitation, drought conditions has been worsening in recent years. There have been 9 consecutive drought years in the last decade, with the most severe drought period being 2003-2005, during which, local grass withered as soon as it sprouted. Consequently, half of the farmers could not adequately feed their livestock due to insufficient forage material. Accompanying this, plant diseases and pests also increased in prevalence.

A combination of decreasing precipitation and an increase in irrigated area has resulted in a drop in the level of groundwater from 200 *mu* to 300 *mu*/per well. This transition in irrigation schemes has altered the balance of the local ground water system – extraction exceeding its compensation. In addition, local farmers have reclaimed land illegally in pursuit of their own interests, leading to a rapid expansion of farmland. As a result of this individual exploitation of water resources, irrigation has become more and more difficult. Moreover, salt water intrusion to groundwater has become more and more serious since 1990s. With the well water employed mainly in farmland irrigation and drinking for livestock, this activity has also transferred salt problems to surface water, and even reduced local crop production by 20%, - 80% in some places. Further outcomes have been the death of local seedlings in their seedling stage and a withering of shelter-belt woodland. Salinization appeared in the 1990s and is now a serious problem in the area.

Sandstorms and land desertification have become more and more serious in recent years (though a few local trees have the capacity to act as windbreaks). The area is well known as an origin area for sandstorms in China, which are often generated from April to mid-June. Surprisingly, 80% of local trees have withered as a result of the drought during the past decade. A serious problem is that the trees are not able to regenerate in time. This is further complicated by the pest – Cerambycidae – which can seriously damage the trees and decrease the resilience of shelter-belt woodlands. As a consequence the wind-resistant capacity of the shelter woodland has been weakened. Soil compaction is yet another problem affecting agricultural practice. This results from excessive use of chemical fertilizer in pursuit of higher crop yields, though can lead to a lack of nitrogen, phosphorus, and potassium. At present, the farmers continue to fertilize their farmland with chemical products because farmyard manures are insufficient for their farmland, being one-third of what is needed (owing to reduction of livestock hold since grazing ban). Overall, the picture is of an increase in the use of chemical fertilization year by year, leading to a decrease in the organic matter content of soil and imbalance in soil nutrient ratio.

As a final point, the so-called dry-hot wind may have a greater impact under climate change. It happens approximately every three to five years in the area, and can have a significant impact on crops, especially wheat.

4.4.3.2 Adaptation measures

Several new measures have been introduced for climate change adaptation in Barunbieli. The first is to ban illegal reclamation, to have stricter control over newly-drilled wells, and to promote water-saving irrigation techniques, i.e. plastic-pipe irrigation, supported mainly by government subsidies. At present there are over 6000 *mu* underground pipe-irrigation farmlands in an area of 80,000 *mu*. 12 out of 15 villages have used the pipe-irrigation technique. In addition the farmers began to use natural spring water from Helan Mountain as a substitute for drinking water due to the drop in ground water and salt-water intrusion. The second measure was the introduction of a grazing ban, a well-known policy for grassland degradation. Since the policy was issued in 1999 the ecosystem of Helan Mountain has been greatly improved. Vegetation is recovering with an extension of its cover rate and a decrease in the content of sands and stones carried by wind. Shelter-belt woodland were planted at the edge of farmland to prevent them strong wind damage. The third adaptation measure is to improve soil quality. The 'soil-testing' and 'fertilizer formula' can be applied in testing soil fertilization in accordance with the actual needs of farmland, being run by government. The implementation of the project is also supported by government subsidies. Another fertilisation alternative is the use of crop straw to increase soil organic matter.

A fourth option relates to adjustments in the structure of cultivation regimes. As noted, the main crops in the area are corn, sun flower, water melon, and wheat. Wheat had been a dominant crop in 1990s, but it has been largely replaced by corn and several economic crops in recent years. Before 1995 60% farmlands were sowed with wheat and 40% with corn, but now the proportions are 60% of corn, 10% of wheat, and 30% of economic crops such as sun flower and water melon. Corn and sunflower are two drought-resistant species, with high yield, high economic benefit and lower water demand. Corn straw can also be taken as animal feed, while sunflower is also a saline-alkali tolerant plant. The shrinkage in wheat cultivation is mainly due to its vulnerability to dry-hot wind. Moreover, a new policy was launched for the strict management of forest and land use, and against farmland expansion. About 30,000 *mu* croplands have been cultivated illegally in the past decade in Barunbieli. Now local government is trying to restore this land through the implementation of the 'Barun Township local government regulation' which was released on 25 May 2008 and is cited as 'Barun Zhengfa [2008]-29'. The act urges local farmers who have illegally cultivated lands to alter land use to promote options such as shelterbelt woodland, irrigation channels, and flood buffer zones by the end of this growing season.

The final adaptation measures being considered are the promotion of agriculture insurance to spread risk and enhance local resilience to climate-related hazards, and to increase scientific and technical training for local farmers and herdsmen so as to provide them with knowledge about changes to farming methods, for instance, the introduction of greenhouses, transferring employment and action in this large area.

4.4.3.3 Problems and policy analysis

Various problems with local-scale adaptation strategies have been identified. For instance, government subsidies for shelter-belt woodland are considered insufficient, leading to difficulties in the management and irrigation of crop plantations. Furthermore, although trees were planted by farmers, they cannot get direct benefits from them, because they have no right to cut them after they mature. As a result of these conflicts, non-healthy trees could not be replaced in time, which weakened the protection function of the shelter woodland against wind.

Insufficient funding is also a problem in the implementation of water-saving irrigation projects even though the government has promoted the techniques with subsidies. As a consequence, the preferential policy for pipe-irrigation has not yet become popular in the area. Meanwhile a rapid increase in price (for instance, in the cost fertilizer) , as a result of worldwide inflation, has become one of the important obstacles in the implementation of adaptation and mitigation policies. The problem of inflation is also reflected in the high price of agricultural insurance. This is further complicated by the fact that insurance companies are only like to insure the less risky crops, rather than high risk ones under changing climatic conditions. It is therefore recommended that the government should consider those structural stressors associated with prevailing market conditions when devising policies for climate change adaptation and mitigation.

A key finding was the opportunity for the greater promotion of 'learning to adapt' by stakeholders. Interviews revealed that local farmers and herdsmen have paid limited attention to climate change so far, and their awareness of climate-related risks is poor. Indeed, individual farmer remain unaware of potential measures for climate change adaptation, and tend to rely on Government help to compensate for the impact of extreme events. More proactive responses, and improved communication between policy-makers and local farmers and herdsmen, would clearly be of benefit. Currently, individual farmers usually liaise with the head of their village or township if needed, and this can restrict access to knowledge of new management techniques for improving their crop production. A further issue relates to economics and a lack of market information. For example, the farmers borrow money to cultivate land in the spring and repay in autumn. However, this arrangement may be affected by the impact of several years of drought. In addition, a lack of market information is also one of the major reasons for preventing herdsmen from practicing dynamic livestock management, which means that in years of drought herdsmen have problems selling livestock and ensuring an appropriate stocking rate. However, Government plays a very limited role in marketing. As one of the reform efforts, the Yaoba Woodland Farm was transformed into a regular agricultural farm, with some of the planted poplar forests areas abandoned for agricultural use. Approximately 30% of the households have biogas facilities that provide energy for cooking and even heating demand, a useful mitigation measure at local scale.

4.4.4 Luanjingtan case

Luanjingtan is a township lying in the southeast of Alxa League (Figure 4.21), close to the Yellow River, and a special ecological and agricultural demonstration zone (typical model on migration) showcased as best practice in the economic development of a migration town (Chen, *et al.*, 2004). The Luanjintan population has now reached about 20,000, half of them being herdsmen that have migrated from steppe rangeland of Alxa League in efforts to prevent the degradation of this vulnerable landscape. It is a Yellow River irrigation area, different from the well-irrigated township of Barunbieli, and was established by the National Development and Planning Commission in 1991 (Ministerial Comission of Water Resources: Shuijizi (90) 195 hao). The total project area is 24.6 million *mu*, and the irrigation area is about 17.2 million *mu* of this. The main hydropower project for the zones was completed in 1993. Several ladder pumping stations were built by the project for pumping Yellow river water in ZhongWei, a county in the southwest of Ning Xia Hui autonomous region (province) and transporting the water to Luanjintan through a channel with four powerful pumping stations with gradually increasing elevation for farmland irrigation. The total length of the water channel is 43.5 kilometres.

Figure 4.21: Maize field with range land and town of Luanjingtan in Alxa League of Inner Mongolia

4.4.4.1 Climate change impacts

According to local interviews the climate change impacts in Luanjintan are very similar to those in the township of Barunbieli. This is perhaps not surprising as the two towns are geographically very close. Here again, drought is perceived as the major climate hazard in the area, adversely affecting the living conditions of both local peasants and herdsmen. As land degradation has continued, approximately half of local grassland (steppe) has been transformed into desert or semi-desert with shrinkages in surface vegetation cover. Meanwhile many lakes have shrunk or even disappeared. 30 years ago this area (basin) was filled with water with high grass, but now only sparse steppe and harsh land are left. Strong wind in the area is harmful to shelter-belt woodland. Some of the trees have withered as a consequence of severe drought conditions. A further problem is the substantial decrease in the level of groundwater - the table even exceeds a depth of 100m although local irrigation of farmland depends on the Yellow River water. Salinization and basification is serious in the area due to absence of enough rainfall (130 mm) and dry climate. There may also be issues of frost hazards as growing seasons start earlier and earlier as a consequence of warming in the region.

4.4.4.2 Adaptation strategies at local level

Several adaptation measures addressing water resource scarcity and land degradation have been implemented in the township. The first of these is to improve the water transfer channels of the irrigation system. The old channels carrying water from the Yellow River were generally made of stone and mud, which resulted in large losses from leakage. Later on, the channels were gradually updated with cement, leading to a 30% water saving rate and substantial increases in crop production. Secondly, vegetation rehabilitation was launched in 2003. This was combined with the stockading of animals – now mostly reared in sheds by local immigrants and farmers. The third part of the adaptation armoury is migration. Increasing numbers of herdsmen have migrated to Luanjingtan, and they are offered farming-skill training courses made regularly by government in order to enhance their adaptive capacity and living conditions. Institutional changes are the fourth development. This is exemplified by the establishment of a number of water-use associations which were set up to clarify responsibilities of water usage and to enable peer to peer communication between those in similar situations. The fifth measure was the introduction of a natural hazard insurance system local farmers and immigrants. Such schemes are usually partially supported by government and endowments from outside the region. Here again, inhabitants of the village have begun to turn to alternative measures of fuel (serving both adaptation and mitigation objectives), using wind power or natural gas instead of wood or grass fuels for cooking and heating purposes, hence preventing surface vegetation damage.

4.4.4.3 Problem analysis

The adaptation measures implemented in Luanjingtan have had both positive and negative impacts on the local ecosystem. Unexpectedly, the grassland in some grazing-ban domains has actually deteriorated because some of local species, *Nitraria* for example, need grazing for their regeneration during its life cycles. This finding highlights that a managed level of grazing may be necessary for keeping the local ecosystem in a good state. However, ensuring an optimal level of grazing is complicated due to the limited pasture area and the complexities of managing this practice.

Problems have also been identified with the emigration initiative. Migration as a key adaptation option has been widely implemented in arid and semi-arid zones, with Luanjingtan considered an example of best practice. However, it is clear that the rapid expansion in immigrant population has brought additional pressure to local oases, with implications for future carrying capacity. Several new problems have also emerged from the analysis, such as an increase in water consumption, a drop in the level of groundwater, illegal reclamation, other issues with increased urbanization, etc. Hence the capacity of oases for supporting future migration needs to be appraised in the policy-making stage.

Other issues also need to be considered if sustainable development of the town is to occur. The facilities for transferring Yellow River irrigation water need to be frequently repaired and updated in order to keep their functions. Nowadays, many machines or equipments are aging due to lack of persistent funding for their updating. New public-private ventures may provide one option for overcoming this. Knowledge will also be important - many trees in shelterbelt woodland around Luanjingtan have withered or even died because they are not well-adapted to new climate conditions, and the local salty and alkaline soil. Greater use of local, and resilient, species will need to be considered if the effectiveness of shelterbelts is to be maintained in the longer term.

4.4.5 Irrigation strategies as adaptation options

The efficiency of using irrigating water and fertilizer is still very low in the region even though agricultural production has increased. Traditional crop varieties still dominate the landscape, although more drought/pest resistant varieties of corn, wheat, and other crops have been available for many years (highlighting the importance of education). Water wastage in irrigation remains considerable as a result of continuing open surface irrigation and free water use, with the application of water saving technologies (pipeline irrigation and irrigation on demand have performed well in several experimental sites) not widely accepted amongst the local farming community.

Table 4.2: National significance of some key variables

Variables	Alxa	China average	Percentage
Precipitation (mm)	122	726	16.8%
Water resources (billion m3)	1.17	2800	0.042%
Unit area water (m3/km2)	22,600	318310	7.1%
Irrigation efficiency	0.44	0.55	80%
Forest production (m3/ha)	1.12	1.84	60.9%
Non-irrigated crop production (kg/mu)	36	124	29.0%
Desert steppe production (kg/mu)	53	67-134	
Per capita grain (kg)	634.2	317.1	200%
Fertilization (kg/ha)	1950	333.33	585%

The grain production per cubic meter irrigation is only 0.85 kg; the irrigation efficiency is only 0.44, or 80% of the national level. The use of fertilizer increased from 178.2 kg/ha in 1970 to 1950 kg/ha in 2002, but the efficiency is still very low. For example, the efficiency for nitrogen fertilizer is 30% compared to the national level of 40%. This is mainly caused by improper N:P:K ratio, which is 86.6:12.7:0.7 in 2002. The proportion of organic fertilizer, mainly from livestock manure, has sharply declined since the grazing ban, forcing farmers to spend more on inorganic fertilizer with negative consequences for soil texture.

As mentioned in previous sections, agriculture in the project area depends heavily on irrigation, and irrigated cropland is mainly distributed in river valleys and the oases between the sand dunes and the Helan Mountain Piedmont. Most rain-fed land that was cultivated previously is now left fallow and has been abandoned, resulting in “ghost town” villages (Figure 4.22). People have moved to new countryside villages with government subsidies of housing, irrigated croplands, and basic facilities.

Figure 4.22: Abandoned villages and farmlands; a common phenomena in severely degraded areas.

By 2005 there were 320,000 ha of irrigated cropland in Alxa, concentrated in several oases such as Luanjingtan, Yaobatan, etc. As a large portion of degraded rangeland in the region was closed under the grazing ban policy, irrigated agriculture in the oases became an important alternative livelihood for former herdsmen. Thus to find a good irrigation strategy is extremely important.

4.4.6 Jilantai case

Jilantai is a salt-producing town near by Jilaitai salt lake (39° 46'59"N, 105° 37'31"E). High quality salt is its main commercial product which it provides for other provinces of China (Figure 4.23). There are one agriculture village with a cropland area of 4900 *mu*, and seven herdsman villages with 46 thousands of animals. Total population is about 30,000, and most of these came to Jilantai after the building of the Wuhai-Jilantai railway in the 1970s. The population increase, with associated expansion of farmland and forage plantation, has led to increasing problems of water scarcity. In the past this has been countered by extracting more and more ground water to meet the demands of irrigation, industry and the provision of drinking water. The over-exploitation of ground water is now causing serious environmental problems and water efficiency has become an urgent task for local residents.

Figure 4.23: Jilantai salt lake in Alxa League

Water consumption on civil construction and living has increased rapidly from 6.8 million m^3 in 1985 up to 11.7 million m^3 in 2000, while the cropland irrigation had increased from 10.15 million m^3 in 1985 to 20.01 million m^3 in 2000. Hence, farming activity is the most water-consuming factor in the Jilantai area. Investigation of the local arable land shows that their plantations are comprised of: 40% for maize, 10% for wheat, and 30% for cash crop (e.g., sunflower). As noted, the rapid increase of crop irrigation has caused rapid drop of local ground water table with associated problems of desalinization. If the intrusion worsens further local agriculture may disappear in the near future.

With climate change as an additional stressor, it is therefore critical that the use of irrigation is optimised to ensure the sustainable use of water into the future. To this end, this study has investigated optimal irrigation strategies, balanced by ecological considerations, in maize growth processes by undertaking numerical simulations with different irrigation levels and future climate scenarios. A summary of the main results are presented below.

4.4.6.1 Model validation and data

The crop model used for this study is coupled with a climate model and is one widely used in climate change impacts and adaptation assessments in agriculture world-wide (Liu, et al., 2002; Gao, 2002; Xie, et al., 2002). The CERES-maize model is also widely used in simulating maize growth and yield in China (Zalud, et al., 2002, Jin, et al., 1996; Chen, et al., 1997; Fan, et al., 2001; Li, et al., 2002; Zhang, 2004; 2005; Xiong, et al., 2005, 2006; Ju, et al., 2006), and the fitness of the model for maize plantation in China was verified by Hu (Hu, et al., 2008). The model calibration involved two steps, one of which one was at station-level. Zhang (2004) and Ju (2006) made the calibration with field experiment data at Quzhou and Shouyang stations, and Hu (2008) completed a calibration in maize plantation zones with a group of long-term data sets observed at many agriculture stations across China. The model inputs included a series of soil components, meteorological records, genetic coefficients, management data, etc. Its outputs were crop calendar, yield constituents, water balance and nutrients, which can be used to analyze climate change impacts and potential adaptation measures. The numerical simulation focuses only on local maize plantation in Jilantai due to a lack of sufficient observation data resources in other areas of Alxa League. The observations for model input are only available for 2003 and 2004 at Jilantai agriculture station for maize simulation, including rowing calendar, management and yield constituent. The soil data comes from *China's Soil Species* (1993—1996). Climate inputs are daily maximum/minimum temperatures, precipitation, and solar radiation for 2003-2004. The climate scenarios used in the simulation were produced by PRECIS, a regional climate model of UK Hadley centre (Jones, 2004), with which the daily outputs of climate baseline (1961-1990) and future climate scenarios in 2080s (2071-2100) are produced under SRES A2 and B2 scenarios (Nakićenović, et al., 2000). The maize variety in Jilantai is '*Yedan 19*'. Its genetic coefficients are calculated from the observations in 2003 and validated with observation data in 2004. The results, listed in Table 4.2, demonstrate that the simulation capacity on growing calendar is better than the yield, to which the simulation bias is below 13%. Hence, the model can be used to estimate the potential impacts of future climate change on the Jilantai maize plantation.

Table 4.3: Simulation and observation at Jilantai station

Year	Flowering date (day)		Maturity date (day)		Yield（kg/hm²）		Biomass（kg/hm²）	
	Observation	simulation	Observation	simulation	Observation	simulation	Observation	simulation
2003	73	74	154	154	13,475	11,740	24,087	18,407
2004	74	72	154	156	13,725	12,202	23,202	19,063

4.4.6.2 Numerical experiments and results

The growing calendar of maize was simulated in the first group of numerical experiments with two runs of the model - no irrigation and sufficient irrigation; because of low and infrequent precipitation (70-80mm) in Jilaintai. The effects of different irrigation strategies in the maize plantations were isolated in the modelling to determine optimal irrigation levels. Table 4.3 demonstrates that the maize growth is seriously hampered without irrigation due to the lack of input water, and a growing season that is thus reduced by 40%. While under conditions of sufficient irrigation, the simulated full irrigation amount is about 375mm, in comparison with actual irrigation amount 776mm i.e. twice the amount of the optimal irrigation amount found in the numerical simulation. This reveals a large quantity of wastage in current practice at the Jilantai maize plantation.

Table 4.4: Actual irrigation and simulations in maize plantation with and without sufficient irrigation

Treatments	Flowering date(Day)	Maturity date(day)	Biomass（kg/hm^2）	Yield (kg/hm^2)	Seasonal irrigation (mm)	Seasonal precipitation (mm)
Actual irrigation	74	154	24,087	13,475	776	105
No irrigation	74	92	3,294	160	0	44
Sufficient irrigation	74	154	20,846	12,612	375	105

The genetic coefficients of *Yedan 19* were estimated from the simulation. Furthermore, we set five irrigation levels (no irrigation, 25%, 50% and 75% of sufficient irrigation, and total sufficient irrigation) in a second numerical experiment for simulating maize production variation during the 2080s under SRES A2, B2 scenarios to the baseline. The total outputs needed are presented in Table 4.4.

Table 4.5: Maize growth calendar during 2080s under SRES, B2 scenarios to climate baseline (1961-1990) in five irrigation levels

Irrigation level	A2 scenario		B2 scenario		Baseline	
	Flowering date (day)	Maturity date (day)	Flowering date (day)	Maturity date (day)	Flowering date (day)	Maturity date (day)
Sufficient irrigation	58	110	62	118	72	152
75%	58	110	63	118	-	-
50%	58	109	63	118	-	-
25%	58	107	63	114	-	-
No irrigation	58	106	63	99	-	-

The precipitation and temperature increments under the A2 scenario are generally larger than the B2 scenario (Figure 4.24), which means differing warming shifts from the baseline to the B2 and A2 scenarios, and relative variation of precipitation scenarios to the baseline (93 mm) - within -0.9% ~ 2.8%. It also shows more dry years during 2080s (Figure 4.24). The maize growing season would be shortened by 4-5 days in terms of flowering date and 7-9 days in maturity date under the A2 scenario in comparison with B2 scenario (Table 4.4). The growing season would be significantly shortened during 2080s under both A2 and B2 scenarios if compared with the baseline, because the warmer climate would accelerate the maize growth process, especially in the milking period.

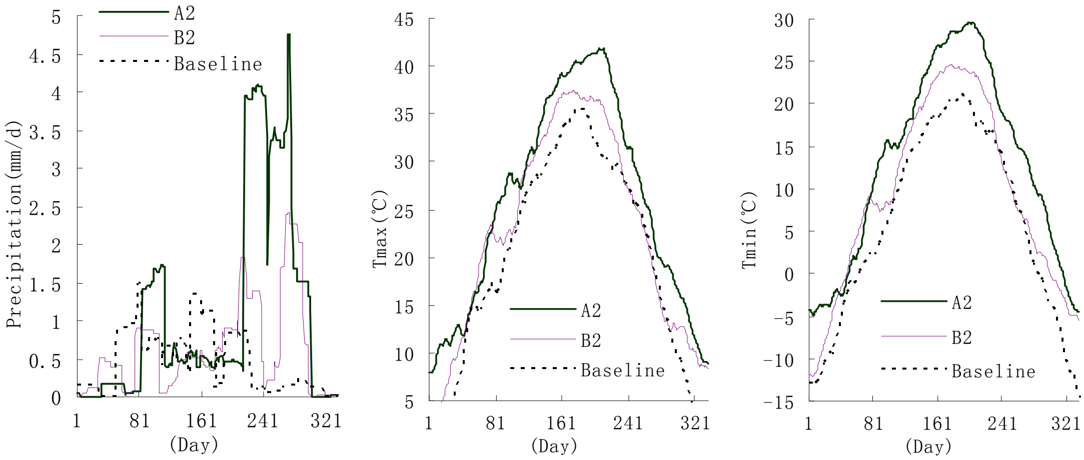


Figure 4.24: Simulation of precipitation, maximum/minimum temperatures in baseline and 2080s under A2 and B2 scenarios at Jilantai station

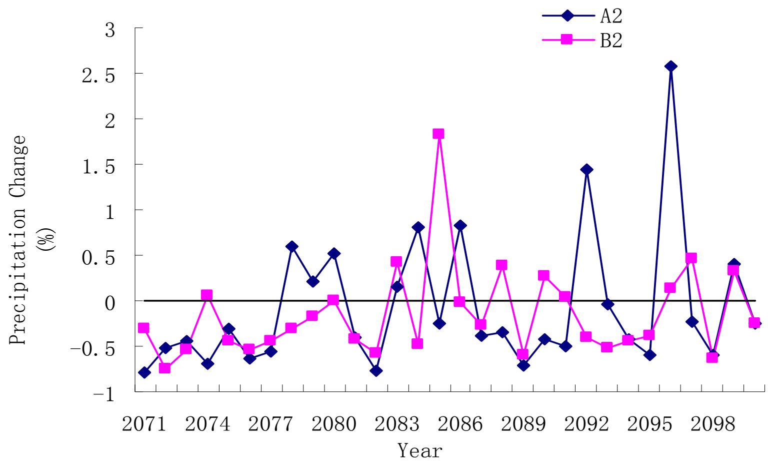


Figure 4.25: Evolution of precipitation during the maize growing season in Jilantai during 2080s under A2 and B2 scenarios to the baseline

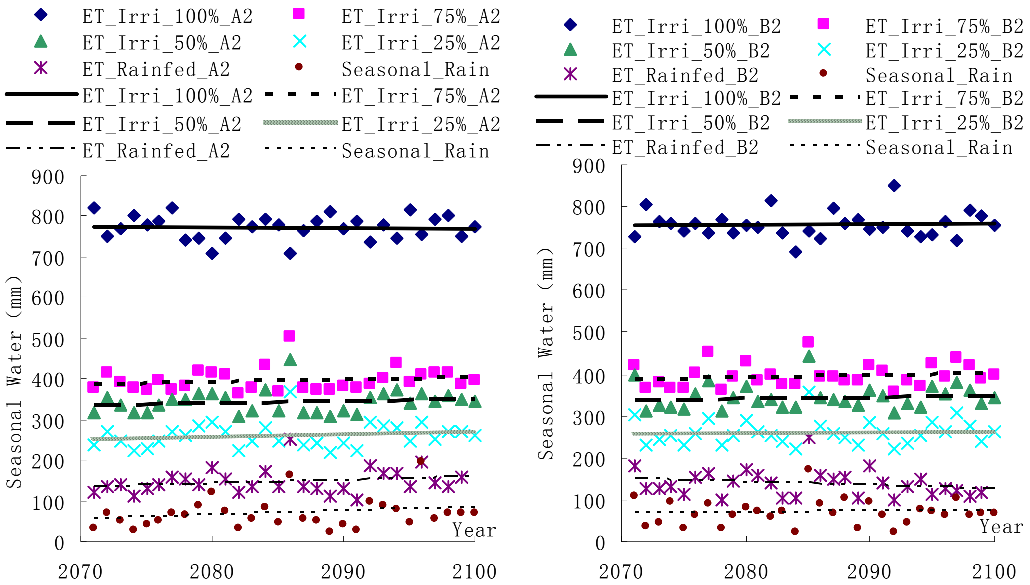
The primary objective of the second group of experiments was to test the efficiency of water use against maize yield. There are several ways to save water in irrigation practice. One of the most effective ways is to control the amount of water used in irrigation whilst simultaneously maximizing the agricultural outputs by promoting water-use efficiency in irrigation. To assess the potential for this, changes in Water Use Efficiency (WUEy) were measured against yield and the Water Use Efficiency (WUEb) against biomass at five irrigation levels (Table 4.5) according to A2 and B2 scenarios. We define WUEy as Yield/ET, and WUEb as Biomass/ET, where ET refers to the evapotranspiration of local maize field.

Table 4.5 and Figure 4.26 show that both yield and biomass, as well as WUEy and WUEb, are lower under the A2 scenario than the B2 scenario, while the ET almost stays the same under the two scenarios. There would be the highest yield, biomass, and ET under conditions of sufficient irrigation, however WUEy and WUEb are lower (the WUEy only being higher than that of the no irrigation situation). The ratios of WUEy and WUEb at 50% irrigation level are highest, about 1.6 times and 1.3 times as much as those representing sufficient irrigation under the A2 or B2 scenarios.

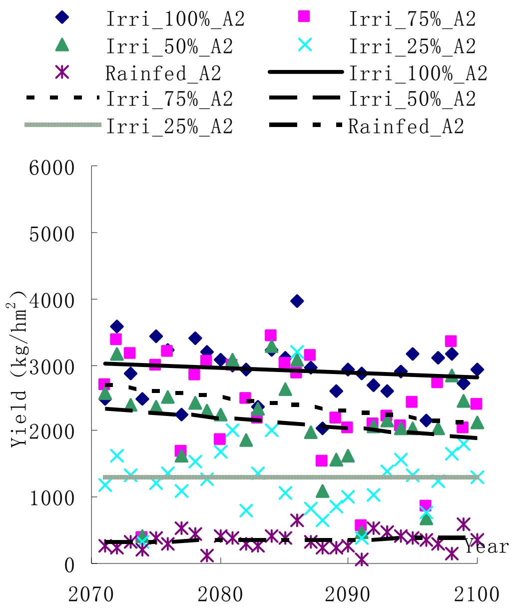
Table 4.6: Changes of water-use efficiency in maize plantation during 2080s under A2 and B2 scenarios at five irrigation levels

Irrigation level	Yield (kg/hm^2)	Biomass (kg/hm^2)	ET (mm)	WUEy (kg/m^3)	WUEb (kg/m^3)
A2 Scenario					
Sufficient irrigation	2,912	10,892	773	0.38	1.41
75%	2,395	7,034	397	0.60	1.77
50%	2,115	6,470	343	0.62	1.89
25%	1,296	4,656	261	0.50	1.78
No irrigation	341	2,386	147	0.23	1.62
B2 Scenario					
Sufficient irrigation	3,473	11,349	757	0.46	1.50
75%	2,989	7,731	397	0.75	1.95
50%	2,630	7,131	345	0.76	2.07
25%	1,505	4,916	261	0.58	1.88
No irrigation	363	2,379	138	0.26	1.72

Moreover, we set irrigation levels with a 5 percent increment around the 50% irrigation level in order to get an optimal point of irrigation (Table 4.6). The results show that the highest WUEy and WUEb appear at about 60% of the sufficient irrigation level, though the yield is below that of 65% irrigation. The yield of per unit water usage is 5.67 kg/hm^2 per mm at the 65% irrigation level and 6.02 kg/hm^2 per mm at 60% irrigation level, respectively. Comparing these results with the A2 scenario, the 55% irrigation level is the optimal choice. Findings indicate that 60% and 55% irrigation levels are the optimal irrigation levels under A2 and B2 scenarios respectively.



(a) (b)



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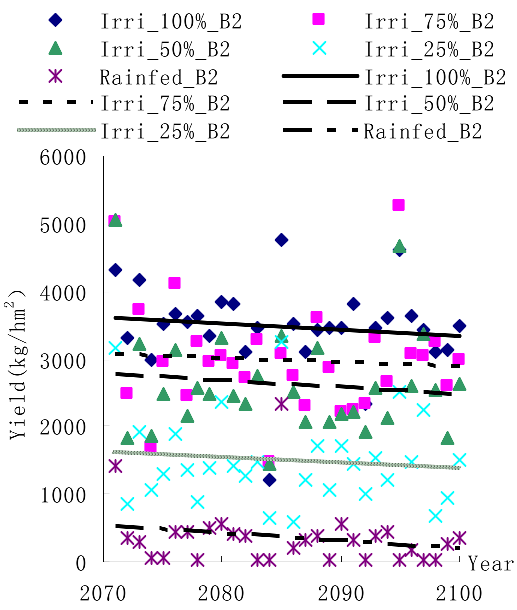

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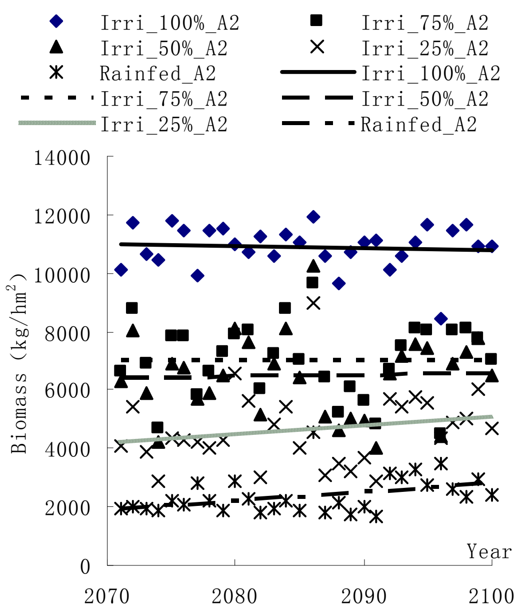

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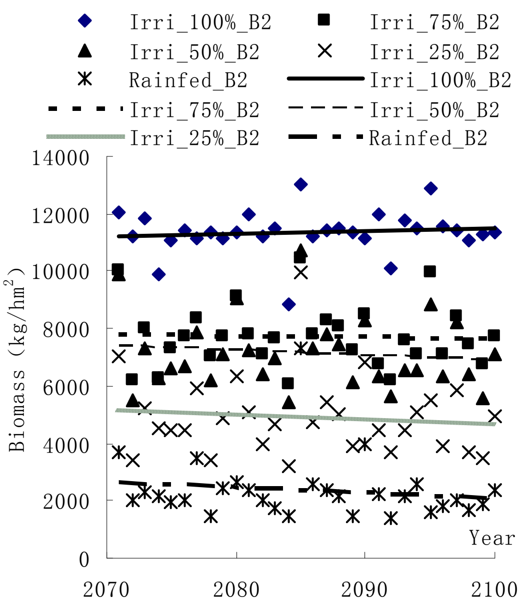

(f)

Figure 4.26: Maize yield against water-use efficiency at five irrigation levels during 2080s under A2 and B2 scenarios.

Table 4.7: Changes of maize water-use efficiency in 2080s under A2 and B2 scenarios with 6 irrigation levels in 5 percent increment

Irrigation level	Yield (kg/hm^2)	Biomass (kg/hm^2)	ET (mm)	WUEy (kg/ m^3)	WUEb (kg/m^3)
			A2 Scenario		
65%	2,419	6,947	380	0.64	1.83
60%*	2,356	6,833	368	0.64	1.86
55%	2,263	6,682	357	0.63	1.87
50%	2,115	6,470	343	0.62	1.89
45%	1,928	6,155	327	0.59	1.88
40%	1,827	5,895	313	0.58	1.89
			B2 Scenario		
65%	2,958	8,141	382	0.77	2.13
60%	2,895	8,040	371	0.78	2.17
55%*	2,862	7,918	359	0.80	2.21
50%	2,630	7,131	345	0.76	2.07
45%	2,632	7,488	332	0.79	2.25
40%	2,430	7,105	317	0.77	2.24

4.4.6.3 Discussion and recommendations

Results from the numerical simulations indicate that current irrigation practice may be excessive for the Jilantai maize plantation. Optimal levels of irrigation would be about half of the present irrigation level although the simulated maize yield does not reach its maximum value. Specifically, 60% and 55% of the sufficient irrigation level would be approximately optimal choices for maize plantation during the 2080s period under A2 and B2 scenarios. The deployment of advanced irrigation systems and the reduction of local farmland areas are two other choices for responding to water scarcity pressure in Jilantai (this would involve a reduction in farmer numbers and better control of new reclamation). In addition, the development of a bigger salt industry at Jilantai Salt Lake, as projected in the 'Eleven-five Year Plan' of Alxa League, could provide those currently involved with farming with an opportunity to seek alternative employment. The reduction in food output could potentially be sourced from adjacent provinces, like Ningxia, compensated by Government funding. Furthermore, Jilantai Salt Lake is a very famous sightseeing town in China. Greater development of eco-tourism could also be considered an alternative adaptation option to cope with climate change and environmental degradation.

4.4.7 Obstacles and conclusion

One of the key obstacles to adaptation is the continued use of less effective agricultural practice. For instance, advanced water-saving technology and no-tillage methods have yet to be widely used in Alxa due to a lack of training and mainstream promotion (wheat varieties used today in the region are as same as that used in 1980s). One improvement suggested is an updating of local cultivation techniques and the introduction of new drought-resistant crop varieties for local farms to cope with climate change. Further barriers that need to be overcome are institutional and relate to management activity. In Barunbieli, the administrative heads of villages have tended to focus on the control of water consumption rather than seek to promote water-saving technology in irrigation, with more attention paid to local GDP growth at the expense of ecological issues. Hence, new institutional arrangements and policies for water management and usage in Alxa League would benefit adaptation efforts in the region. Cultivation of marginal land, e.g. at the edge of sandy deserts and oasis, is a key human driving force influencing desertification. This is a specific issue that will need to be addressed when mainstreaming adaptation measures into regional and local policy making.

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4.5 Impacts of grazing on desertification

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The scoping stage of the Inner Mongolia case study highlighted the importance of desertification. In particular, over-grazing was considered one of the most serious problems causing grassland degradation in Inner Mongolia under global warming. Various grazing strategies are currently implemented to combat desertification in this region. These include rotational grazing, periodic- or seasonal grazing, a complete grazing ban, and grazing in enclosed areas only. Ideally, should the grazing strategy applied depend on the local climate, especially on precipitation, because of its large inter-annual variation. A grazing ban has been widely employed in the Alxa League, west Inner Mongolia, which led to a significant restoration of the local ecosystem. However, different opinions were raised against the grazing ban during in-depth interviews and stakeholder workshops, stating that limited or controlled grazing may be necessary for both herb and shrub regeneration, and to reduce accumulation of litter, which increases the potential of wild fire.

The interaction of grazing, grazing strategies, vegetation cover and desertification was identified as both crucial in adaptation to climate change and an important knowledge gap. To study that complex interaction, it was decided to parameterise and subsequently apply the model FORSPACE, developed at Alterra, for the Inner Mongolia case study. We designed a series of simulation experiments to assess whether a limited grazing could be permitted in a dry steppe of west Inner Mongolia. The experience with the use of FORSPACE in Inner Mongolia and preliminary results are presented here.

The structure of this contribution is that, first, a general description of the model FORSPACE is presented, with special emphasis on how ungulates are described because of their particular importance for the Inner Mongolia ecosystem. Next, preliminary results are presented and discussed, and some conclusions are drawn.

4.5.1 General description of the model FORSPACE

FORSPACE, an acronym for forest dynamics in spatially changing environments, is a spatially explicit model that simulates ecosystem dynamics at the scale of a landscape (up to several 1000's of hectares). The ecosystem's vertical structure is represented by cohorts of either dominant species of plant functional types in the herb-, shrub- and tree layer. For herbs and grasses, the dynamics in coverage per plot is tracked by the model.

Grazing by ungulates is an important aspect of ecosystem dynamics because it has a strong effect on the natural regeneration of seedlings from trees and shrubs. On the other hand, the ecosystem provides food for ungulates, in particular by herbs and grasses. The productivity of the herbs and grasses in the understory is driven by the available light, water, and nutrients, but also by the local management. Thus, there are strong interactions between ungulate grazing pressure and the dynamics of herbs, grasses, shrubs, and trees and the succession of the ecosystem. FORSPACE contains a mechanistic description of these interactions. A full description of processes driving the dynamics of the vegetation can be found in (Kramer, 2001), (Kramer et al., 2003, Kramer et al., 2006) and (Groen et al., 2000).

4.5.2 Modelling grazing dynamics: ungulates

Because of the particular importance of ungulates for the Inner Mongolia case study more information on of the modelling of ungulates is presented below. The ungulate populations are described by the weight and number of both juvenile and adult cohorts for each ungulate species. The mean body weight of the animals within these cohorts is derived by dividing the cohort weight by the number of animals in it. Thus within each cohort, animals are not distinguished by either weight or gender.

The rate of change of weight for each cohort is the net result of input of energy by consumption of plants, and loss of energy by pregnancy, lactation and maintenance. Consumption is the intake of food from a simulated plot, which can include foliage and branches from trees, shrubs, and herbs; seeds of trees; and roots of herbs. The food items of each plant species are characterised, for each ungulate species, by the amount of energy available after digestion. The energy content of a kilogram dry mass differs between plant species and varies over the year. The selection of plots by the ungulate follows a 'top-down search': all high quality plots that contain most energy are selected first, thus assuming that the animals maximise their energy intake rate (Wieren, 1996). Several ungulate species may "wish to" consume the same food item. Therefore, to avoid over-consumption, the intake of the food available on a plot is scaled proportionally with the relative energy content the food represents for a given ungulate species compared to the other ungulate species. Similarly, to avoid over-intake, the maximum intake of the ungulate is not exceeded. The quality of a plot for an ungulate species is defined as the preference for a plot relative to the plot with the highest preference in the area. The preference of an ungulate for the trees (including seeds from trees), shrubs, and herbs (including roots from herbs) is based on the digestibility of these food sources in a plot. This assumes that the ungulates are mobile across the entire area within the one month time step of the simulation. Pregnancy is simulated as the energy required for growth of the foetus. It depends on the fraction of the population of reproductive animals that are pregnant and on the monthly cost of pregnancy, which is allometrically scaled to the mean body weight of the animal. Lactation is the transfer of energy from the parent to the young. It depends on the number of juveniles and on the monthly energy cost of lactation, which is allometrically scaled to the mean body weight of the animal. Maintenance is the energy required to cover metabolic costs. It depends on the number of animals and on the monthly cost of maintenance, which is allometrically scaled to the mean body weight of the animal. The coefficient of maintenance describing the energy need per metabolic biomass and per month, also depends on mean body weight. A linear decrease in maintenance energy requirement from a maximum to a minimum value is assumed as the mean body weight decreases from an upper to a lower threshold. In case of birth of young, maintenance cost for juveniles is based on the number of newborn. The change in numbers of ungulates depends on mortality and birth. Mortality can occur due to two reasons. First, an animal dies if its mean body weight falls below the minimum weight. The maximum number of animals is the total weight of the cohort divided by the minimum body weight. Mortality occurs if this maximum is less than the actual numbers. Second, mortality occurs if the maximum age is reached. The number of young born annually depends on the maximum number of young produced by the reproductive age individuals, and the fraction of the total adult cohort that is pregnant.

4.5.3 Model input and experiment design

The simulated area is situated in the Azou Banner of Alxa League in the west piedmont of Helan Mountain. The west-south corner is located at 105ºE and 39ºN. The plot consists of 29×17 cells with a cell size of 70m×70 m. Input climate data are daily values of precipitation, mean temperature, solar radiation, surface wind and surface vapour pressure. These were obtained from CRU (Climate Research Unit) grid data sets (Mitchell et al, 2003). The analytical daily precipitation was made using the method described in Xie and Arkin (1996). The time step is one month.

The Alxa region has an arid climate with rare precipitation and hot summer. July is both the warmest and the wettest month (Figure 4.27), with an additional rainfall peak in October, unlike the east monsoon zone of China. In the periods January to March and November to December there is almost no precipitation.

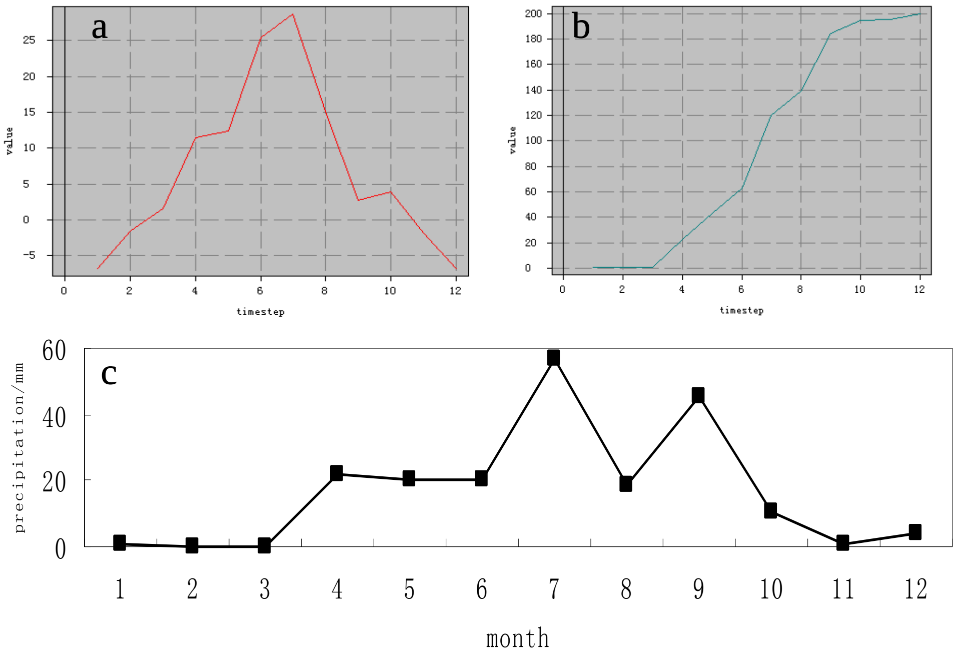

Figure 4.27: Temperature and precipitation at model plot for 1999; (a): monthly temperature; (6): accumulated precipitation; (c): monthly precipitation

The stock-carrying capacity is about 21 sheep per 100 hectare on average (Editor group of Alxa Choragraphy, 2000) in the pasturing area of Azou Banner of Alxa League. Over-grazing before the year 2000 led to serious grassland degradation in the area. However, the vegetation was able to restore due to the grazing ban or enclosure implemented in the area since 2000. During the ADAM stakeholder workshop in Alxa in 2009, the suggestion was raised that limited and variable pasturing could be allowed in favour of vegetation renewal, especially for some of local shrubs. In this section a number of simulation experiments were performed with varying number of sheep and goat. To assess the consequences of a possible lift of the grazing ban a number of simulation experiments were performed. Therefore, the model FORSPACE was parametrised for four dominant plant species occurring in west piedmont of Helan Mountain. These include two shrub species (*Reaumuris soongolica; Salsola passerina*), a perennial deciduous grass (*Stipa breviflora*) and a perennial deciduous herb (*Zygophyllum xanthoxylum*) (Figure 4.28).

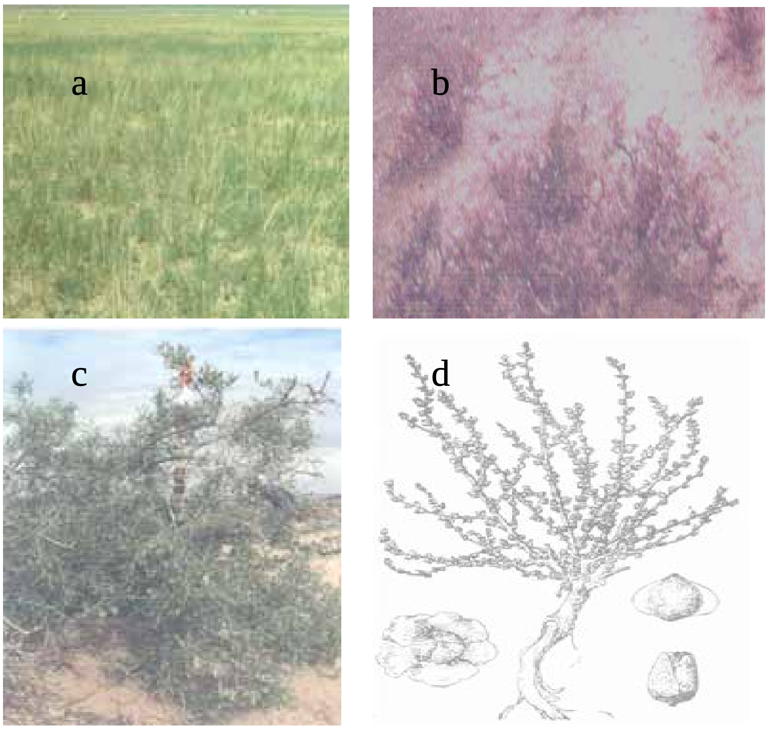

Figure 4.28: Plants in FORSPACE for Inner Mongolia case study; (a): *Stipa breviflora*; (b): *Zygophyllum xanthoxylum*; (c): *Reaumuris soongolica*; (d): *Salsola passerina*

4.5.4 Experiment without animal grazing

Firstly, we considered the situation without grazing to produce a reference state. Figure 4.29 shows simulated monthly net primary productivity (NPP) of the two herbs (*Stipa breviflora; Zygophyllum xanthoxylum*) in 1999 by FORSPACE.

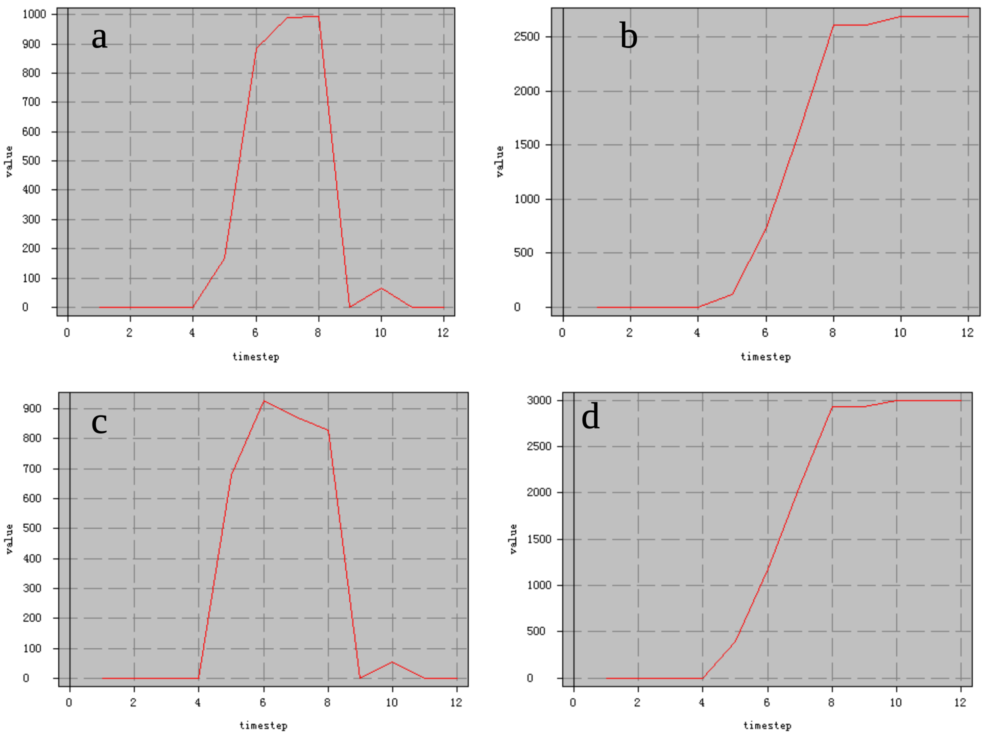

Figure 4.29: Monthly and annually accumulated net primary productivity (kg DM plot^{-1}) for 1999. (a) and (b): *Stipa breviflora*; (c) and (d): *Zygophyllum xanthoxylum*.

NPP of the herbs is highly correlated to seasonal temperature and precipitation (Figure 4.27). The NPP increase from April throughout June and reached its maximum in summer and then sharply descend to zero in September (see Figure 4.29 (a), (c)) although there is a rainfall peak in that month (see Figure 4.27 (c)). This implies the importance of the temperature in plant growth. The monthly mean temperature is about 3°C in September (see Figure 4.27 (a)), which is below the temperature threshold for photosynthesis of the two species. A small increase in NPP appears in October again with a temperature increase by about 4°C, that is, above the critical value for photosynthesis. The annual NPP development shows that there are almost no NPP increase after September (see Figure 4.29 (b) and (d). In addition, annual NPP of *Zygophyllum xanthoxylum* is larger than that of *Stipa breviflora* although the maximum value of the former is less than the latter. Figure 4.29 (a) and (c) implies that it is impossible to feed animals during the April - September. In fact, local herdsmen feed their herbivores during the cold and dry winter season. Hence, in the simulation experiments we set the condition in model that only allows animal grazing in the period from April to September. During the winter period they are artificially fed such that they maintain a constant body weight.

4.5.5 NPP and grazing

NPP evolution changes with animal grazing. Figure 4.30 and Figure 4.31 show how the NPP of the two species is affected by animal grazing at different densities.

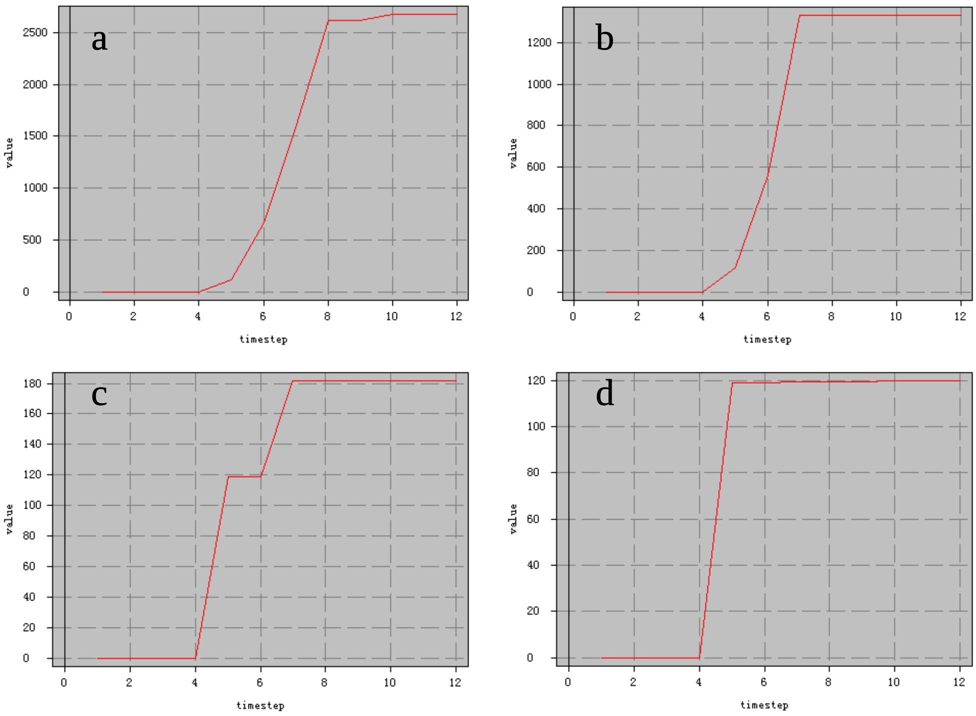

Figure 4.30: Accumulated NPP of *Stipa breviflora* under grazing of one (a), two (b), five (c) and six (d) sheep, respectively, for 1999.

There are almost no changes in NPP between the cases of either one sheep and one goat or no animals (Figure 4.30 (a) and Figure 4.29 (b)). If the animal number is increased by four, i.e. two sheep and two goats, the maximum NPP is reduced by about 1/2 of no-grazing reference (see

Figure 4.30 (b)). If the number of animals is further increased by ten (5 sheep and 5 goats) and twelve (6 sheep and 6 goats), the maximum values of the NPP of the vegetation descends respectively to 180 and 120 kg/plot or 7% and 5% of the reference. It appears that ten or twelve animals exceed the stock-carrying capacity of pasture in the plot. If we assume ten animals as threshold of stock-carrying capacity of the plot, it results in 24 ha per sheep, or about 4 animals per 100 hectare. Actual stocking capacity may be differ from this value because as not all plant species were considered and these may differ in productivity and palatability. Similar situation also appear in *Zygophyllum xanthoxylum* case (see Figure 4.31), but the maximal NPP for ten and twelve animals are about 450 and 400 kg/plot, or 12% and 11%, of the reference NPP without, respectively. This shows that the stock-carrying capacity for *Zygophyllum xanthoxylum* is higher than that of *Stipa breviflora.*

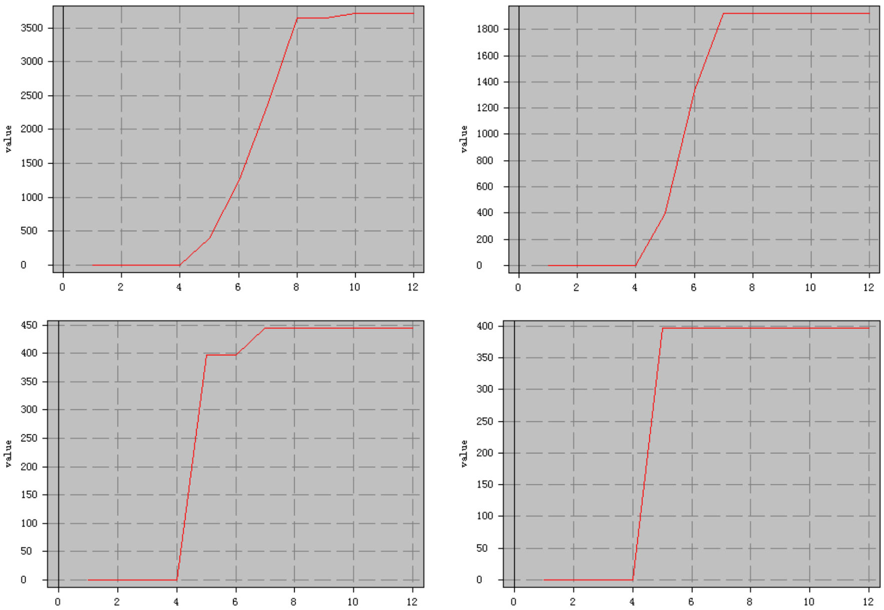

Figure 4.31: Accumulated NPP of *Zygophyllum xanthoxylum* under grazing of one (a), two (b), five (c) and six (d) goats, respectively, for 1999

The individual weight of the animals evolves with NPP and grazing activity. It is a linearly increased rate of their weights for one sheep and one goat case from May to September ((see Figure 4.32 (a) and Figure 4.33 (a)). Their maximum weights, i.e. about 56 kg for sheep and 45 kg for goat, are reached in September, which present a case with sufficient animal food supply under natural stocking. As for two sheep and two goats the NPP firstly is increasing linearly to near 55 kg in August and then descending to a minimum value of about 44.5 kg (see Figure 4.32 (b)) due to lack of food in September (see Figure 4.29 (a), (c)). The case with 5 sheep and 5 goats shows a little increase in their weights from May to June and then falling down to a minimum value (42 kg) in July and then increasing again up to the second peak with weight 46 kg about and descending again down to a final minimum weight about 38 kg. This implies that ten animals are closed to a critical stocking capacity of the plot. When animal number exceeds ten, for example 12 animals (6 sheep and 6 goats), individual weight are decreasing monotonically to a minimum below 30 kg after a little augment from May to June (see Figure 4.32 (d)). This is a case of over-grazing in the plot, which would lead to animal death due to lack of vegetation to graze on.

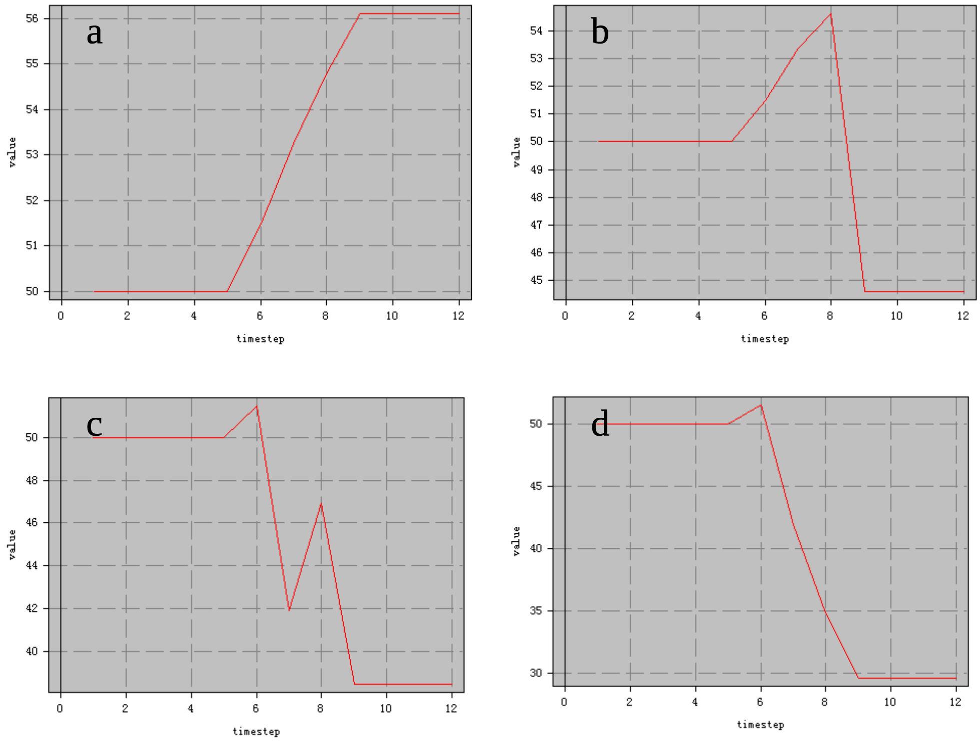

Figure 4.32: Weight evolution of individual sheep with number of animal cohort; (a): one sheep and one goats; (b): two sheep and two goats; (c): five sheep and five goats; (d): six sheep and six goats.

The characteristics of the goat weight evolution are similar to the ones with sheep. Figure 4.33 shows that the stocking capacity of the plot for goat with initial weight of 30 kg is lower than the sheep with initial weight 50 kg. However, goats are destroyers of grassland, Because it also graze plant roots (Bai, 2002). However, this characteristic has not yet been introduced in FORSPACE.

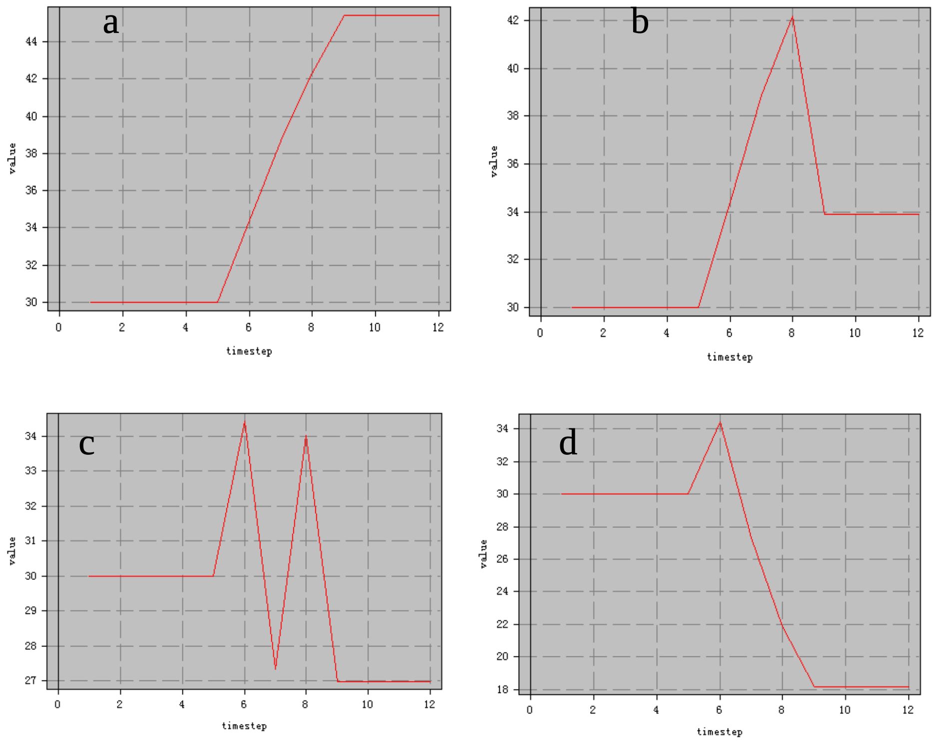

Figure 4.33: Weight evolution of individual goat with number of animal cohort; (a): one sheep and one goats; (b): two sheep and two goats; (c): five sheep and five goats; (d): six sheep and goats.

4.5.6 Discussion and Conclusions

The simulation experiments confirm the capacity of FORSPACE model on simulating the interaction interactions between the vegetation dynamics and animal grazing under local climatic conditions. The preliminary results suggest that a limited grazing could be allowed if it does not exceed the stocking capacity of the plot, while over-grazing would lead to not only the vegetation degradation but also animal death if no additional food is supplied to the animals. The simulated NPP indicates that the period from May throughout September is the suitable period. However, it indicated by stakeholders in the second stakeholder workshop in Alxa in 2009 that some of the local herbs need grazing to regenerate after they reach their maximum age. Furthermore, animal grazing is favourable to the growth of the shrubs. Absence of grazing would in fact lead to their degradation. Hence, limited and control grazing could be considered by the policy makers in the grazing-ban area of Inner Mongolia.

There is still much work to do to make FORSPACE a reliable simulator for the interactions of vegetation development, ungulate grazing, climate change and local management in Inner Mongolia. For instance, many parameters in FORSPACE model need to be more precisely specified, with more observations and laboratory tests. More local dominant plant species and plant functional types should be included and tested in the model to be able to simulate the actual dynamics among climate change, ecosystem, animal grazing, wild fire and human interventions. More long-term simulations should be performed than the one-year simulation experiments presented, as these are particularly sensitive to initial conditions. For example, initial soil water content may affect the results for the first year of the simulation. If that is achieved, more grazing strategies and management options can be considered in future simulation experiments with the model.

An important aspect of a complex process-based ecosystem model such as FORSPACE is that of transfer on knowledge between its developer and the scientists that are applying it for a particular ecosystem, and vice versa, transfer of knowledge on the ecosystem from the local scientists to the model developer for necessary model adjustments.

For the Inner Mongolia case study, the particular ecosystem was outside the experience of the model developer, and the ecosystem model was outside the experience of the scientists that were applying the model. Given the physical distance between model developer and model users (Netherlands and China), only a limited number of face-to-face meetings were feasible. However, the meetings were very productive and based on that much additional specialist information could be transferred easily by email. Although we did not come to a final conclusion on the best grazing strategies for the Inner Mongolia case study, we can conclude that the collaboration was productive. Given the joined interest in the management issues of grazing and climate change in this area of the world, we trust that ADAM project laid the base for a good collaboration in the future.

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4.6 Ecological migration: climate change perception, experience, policy & preparedness

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4.6.1 Introduction and Background

The study reported here explored qualitative perceptions and experiences of ecological migration (*shengtai yimin*) among migrants in Bantanjing village (Right Banner) and Luanjingtan town (Left Banner) in Alxa League, Inner Mongolia autonomous region, China (see Figure 4.1). Inner Mongolia is one of three regional cases in the ADAM project in which opportunities and challenges for mainstreaming climate adaptation and mitigation strategies in regional land-use and water management policies is being explored.

Ecological migration is a central-government mandated, and regionally implemented, policy that aims to deal with deteriorating ecological, as well as social, conditions connected to serious land degradation and desertification in the Western regions of China (Du, 2006; Dickinson and Webber, 2007). While the causes, rates, and outcomes of degradation and desertification in the region are contested, climate variability and change appears to play a role (Dai et al., 2008). Studying perceptions and experiences of ecological migration was therefore expected to yield insights into some of the local challenges and opportunities for climate change adaptation connected to environmental policies in this rapidly changing region.

Ecological migration

Ecological migration has been formally implemented in Alxa League since 2000. However the government has encouraged resettlement of villages and families located in ecologically fragile areas since at least the early 1980s (Du, 2006). As mentioned above, ecological migration is a government-initiated, permanent resettlement of people (mainly herders and mixed livestock keepers/farmers) away from fragile ecological environments and into new or existing settlements outside of ecologically vulnerable regions. The policy aims to protect and rehabilitate degraded ecosystems by moving people off the land, and aims to reduce poverty and encourage economic development through the creation of new, market-oriented livelihoods for migrated populations in the new eco-migrant settlements (Dickinson and Webber, 2007).

An estimated sixty-five percent of Alxa's rangeland is currently degraded, leading to serious reductions in productivity over the past twenty years (Werners et al., 2009). Desertification in the region has led three previously distinct Badain Jaran, Tengger and Ulan Buh deserts to become connected, causing a major increase in the frequency of sand storms, with economic losses and damage experienced both within and beyond the region itself (ibid.).

Policies for reversing degradation and desertification have focused on rehabilitating the region's ecology as well as enhancing livelihoods of land-dependent populations. Policies that address the ecological rehabilitation of the region include grassland enclosures, grazing bans, and conversion of steeply sloped and marginal agricultural land through the "Grain for Green" policy, while policies addressing livelihoods include general poverty alleviation strategies (for example the "Eight-Seven" Poverty Alleviation Reinforcement Plan (1994-2000), economic development strategies (the West Development Strategy), and ecological migration, the focus of this study (see Du, 2006 for a general overview of these policies).

Although the reasons for the widespread desertification and degradation in Inner Mongolia are contested, cultivation of lands at the margin of deserts, increasing livestock numbers in the 1980s and 1990s that likely exceeded the natural carrying capacity of rangelands, and conversion of rangeland to farmland due to increasing population and continuing migration of Han Chinese farmers to the region, have all contributed to land degradation (Dickinson and Webber, 2007). However, the high natural climate variability of the region, and an observed increase in temperatures in recent decades make it difficult to disentangle the relative importance and contribution of anthropogenic, climatic, and other (e.g. policy) drivers of landscape degradation (ibid).

Structure of the paper

The paper begins by describing the field sites and the methods applied in the fieldwork. A description of livelihoods in the two villages based on the fieldwork is provided, followed by summaries of migrants perceptions and experiences of i) government compensation and incentives provided for resettlement, ii) reasons why they were resettled, iii) experience of climate and environmental changes iv) impacts of policies on livelihoods and new livelihood challenges experienced by migrants. A summary and discussion section follows in which climate change adaptation and sustainability actions, challenges and opportunities that were identified during the fieldwork, are presented and discussed.

4.6.2 Methods

Location of fieldwork

The fieldwork was conducted in Bantanjing village (Right Banner) and Luanjingtan town (Left Banner) in Alxa League, Inner Mongolia (Figure 4.1). Alxa League is one of the 9 prefectural-level administrative regions of Inner Mongolia, and is further divided into three administrative divisions called banners (Left, Right and Ejin), which are similar to counties. Inner Mongolia was selected as the study area for the regional case in China within the ADAM project because its arid and semi-arid ecosystems are particularly vulnerable to climate variability and change, and desertification in the region in connection with sandstorms has affected welfare within and beyond the region (ADAM, 2008).

Figure 4.34: Locations of fieldwork in Alxa League, Inner Mongolia, China (*courtesy of Li Shan at CAS Beijing*).

Selection of field sites

Villages were selected by the Alxa Foreign Affairs Department in consultation with Professor Dai at the Chinese Academy of Sciences (CAS). The two villages were selected according to both practical feasibility and distances given a short field schedule, and to offer contrasts in terms of population size, location, remoteness and general living conditions.

Methods

Fifteen semi-structured interviews and three group discussions (of 4-5 participants each) were conducted, in addition to tours of agricultural facilities and fields in and around the towns and general discussions with village heads and senior officials (the Director of Foreign Affairs for Alxa League and the Director of the Luanjingtan water and electricity department) during the trip. An interview guide (appendix 1) was followed for the household interviews. In group discussions broad discussion topics were introduced that aimed to a) confirm general information about the village or government policies conveyed during household interviews, and b) elicit different views on the process of migration, c) gain new information about livelihoods, village history, and prospects for the future. The topic of follow-up questions and themes discussed in groups followed the general progress of the conversation. Deviations were initiated when needed to follow up or clarify information conveyed during household interviews or by participants during the discussion.

Field team

The field team consisted of principle investigator Jennifer West (CICERO), interpreter and doctoral candidate Li Shan (IAP,CAS), Foreign Affairs Minister for Alxa League, Ms. Tuo Ya, and driver Mr. Ba. The fieldwork permissions were arranged and coordinated by Prof. Xingang Dai (CAS) in cooperation with the Alxa Foreign Affairs office, which officially hosted the visit and arranged the logistics and fieldwork itinerary, including the final selection of field sites.

Selection of households and interview setting

Households were selected by village heads in each village according to the researcher's communicated desire to speak with a) both newly established and longer-term residents, b) ethnic Mongolian and Han Chinese respondents, and c) a balance of better-off and poorer households. Given the small sample and non-random selection of households, the findings and conclusions reported here should be interpreted with caution. Interviews took place in respondents' homes, with one or more residents of the household, typically a husband and wife, taking part in the interviews in addition to myself and Li Shan. In some cases other neighbours or family members joined the discussions. Participants in group discussions in the respective villages (between 4 and 5 people) were chosen by the village heads, according to specifications that the groups include both women and ethnic Mongolian households, and a mix of more recent, and established migrants.

We were accompanied to each household interview by the village head. In all but two cases, for which we required translation from Mongolian, interviews were conducted by me, with Li Shan translating. The Director of the Alxa Foreign Affairs Office assisted when needed with translation from Mongolian to Chinese, with Li Shan then translating to English. According to the agreed contract with CAS, each household interviewed received 100 Yuan to compensate them for their time. Village heads who assisted with the identification of respondents and guided us through the villages received 200 Yuan each.

Reflection on the methods employed

The interview guide was designed to gain information about interviewees' qualitative perceptions and experiences of trends and changes in their livelihoods, rather than to try to quantify the effects of the ecological migration policy itself (for a study of the latter see Dickinson and Webber, 2007). Limited time in the field and a small potential sample precluded conducting lengthy surveys. The interview guide was also designed for ease of interpretation and tried to avoid lengthy interviews that might exhaust those being questioned. In general, the household interviews lasted between 45 minutes and 1.5 hours. After interviewing households, on occasion we were given the opportunity to tour interviewees' agricultural fields and livestock holdings. These tours added richness to the interviews, and provided opportunities for more informal discussion.

Group discussions generally seemed to initiate more lively discussion compared to household interviews. However, the quality and usefulness of group discussions varied somewhat according to the diversity of participants and the setting. In the first group discussion in Luanjingtan, participants who had lived in the town for a number of years (i.e. not recent migrants) were specifically targeted for the discussion. This approach worked well, as participants had a lot in common, and could describe the history of settlement in their village very well. In the group discussion in Bantanjing, the only ethnic Mongolian male present spoke very little during the discussion and I wondered whether the presence of the retired village head and several other outspoken residents, and the fact that the discussion took place in the home of the current village head (though he was not present) may have had something to do with this. In the second group discussion in Luanjingtan, the only male participant hardly managed to get a word in edgewise alongside the four other outspoken female participants.

In all cases, a number of cautions relating to the way in which data was collected warrant mention. These include that 1) the investigator had little control over the towns and villages visited; 2) households were selected by village heads, albeit according to voiced criteria based on known information about the villages; 3) interpretation was a necessity and there is potential for misunderstanding and loss of data and meaning during the translation process; 4) those interviewed received payment for their time. This may have led to a feeling of obligation to give the "right" or "correct" answers to questions; and 5) despite the fact that no names were recorded and that those interviewed were told that their identity would be protected, respondents may nonetheless have been hesitant to respond to questions and refrained from speaking openly due to both the sensitive nature of the topic (government policy) and the fact that they were identified by village heads.

4.6.3 Description of villages and livelihoods

4.6.3.1 Bantanjing village

Bantanjing is located about a two-and-a-half hour drive from "Menggen" town[20] and is made up of a number of smaller settlements located close to one another. The village is home to 126 families and has a total population of about 500, including 20 ethnic Mongolian families (in total about 60-70 people). Remaining inhabitants (140 families) are Han Chinese farmers and herders. The village is serviced with tap water (installed in 1998), which is pumped from the ground, and a road, which is currently under construction. The town bus station was officially opened while we were visiting.

The area that is now Bantanjing village was used once a natural oasis, described by villagers as "flowing grassland". The first residents arrived in 1983 during a severe dry spell in 1983-84 during which no rain fell for two consecutive years. Twelve families (around 40 people) migrated from *Xilinbuluge*, a village located at a distance of about 75 km from Bantanjing.

In 1998, the government made a new policy of developing the area around Bantanjing economically, and in 2002, Bantanjing was labelled a "model village" by the government. The major emigration of people to Bantanjing occurred after 1998. The unpaved road connecting the town to the main highway was constructed in 2000, and cell phone coverage was gained in the same year. Electricity provided by solar panels that were installed under a Japanese bilateral aid project in 2002 were not working at the time of our visit and residents complained of electricity shortages. Some, but not all, residents have oil generators to provide for household electricity

[20] The unpaved road was under heavy construction at the time of the fieldwork. It is slated to become a paved highway.

needs. Piped drinking water, pumped from the ground, was completed in 2002 and now services all households.
Although all respondents had herded camels, and in most cases also goats and sheep, before relocating to Bantanjing, the major economic activity in the village is irrigated farming of wheat, corn, sunflower, and cotton. Many households keep several goats and sheep, as well as chickens, for household consumption. Livestock (excluding chickens) are stall-fed with corn and vegetables. Chillies, seed melons, watermelons and vegetables are grown for household consumption as well as sale. The government has constructed greenhouses inside the town for residents as part of the relocation compensation. Some residents who were interviewed have additional non-farm income either seasonally or throughout the year. Examples given among those interviewed were long-haul truck driver, local nurse/doctor, agricultural supplier/stockist for the village, and cook for government officials. Several of those interviewed also rent out, or rent in, additional land for growing agricultural produce. Cultivation of traditional Chinese medicinal plants, mainly *Suo Sua* (a local shrub) and *Cong Rong* (Chinese Wolfberry), a rhizaphilous sub-species of Suo Sua, is undertaken by some households. These high-value plants have been promoted by the government, and provide some residents with a good source of non-farm income. According to one man who was interviewed, the government provides quotas to individual people for growing the medicinal plants, and subsidised the initial cost of the planting seed as well as providing training. *Suo Sua* is grown on non-agricultural land and takes three years from planting until the first harvest. Medicinal plants are also sown as part of re-vegetation efforts around the town, according to the head of the village.
An example of livestock entrepreneurship is one family that is keeping 200 pigs, and receives free government veterinary services and pig stalls. The government recently introduced a policy whereby farmers receive 100 Yuan for every pig they raise on top of sales. The policy aims to increase the supply of pork to the domestic market to combat the steep rise in pork prices experienced in China over the last several years (*Dai, X. personal communication, 2008*).
Free-range grazing of goats and sheep in the surrounding grassland and desert is strictly forbidden. This policy does not apply to camels, however, because they must be allowed to graze in the open and cannot be stall-fed. For those residents still owning camels, camel milk and wool can provide an additional source of income.
Outlying fields surrounding the village are bunded on the perimeters to prevent erosion, and are connected to irrigation facilities. There are about 150 bore wells in and around the village, the first of which was dug in the 1970s. Irrigation water is used for both agricultural crops and for watering trees, shrubs, and other vegetation that has been planted to reduce erosion and desertification under the governments' "grain for green" and grassland rehabilitation policies. According to the village head the ground water table is not being depleted, and the chosen non-agricultural vegetation has low water needs, is based on local varieties, and is effective at stabilising the shifting sand. Perennial bushes planted around the village include desert cistache, red (Chinese) Wolfberry, willow, and *Suo Sua*, as well as a type of long, red-coloured grass that has been introduced to the area. These have been planted over large areas, mainly since 2005, and are maintained by villagers who are compensated under the government's grassland rehabilitation programmes.

4.6.3.2 *Luanjingtan town*

Luanjingtan town is located in the Left Banner of Alxa League. The government designated this area as an ecological and immigration demonstration village 17 years ago. The town is made up of 10 agricultural villages and 10 animal husbandry villages. The population is 11,000 and comprises 120,000 mu of cultivated land, 100,000mu of forest, and 220,000 livestock. Irrigation water for farming is pumped from the Yellow River, nearly 50 km away. The project draws water from the north main canal at Ningxia Zhong Wei County. Water arrives at the irrigation area via four levels of pumping stations. The water canal length is 43.5 km, with a water height/total height of 208/228 meters, an annual water index of 50 million steres[21], and a designed water capacity/flow of 5-6 cubic meters/second. The main canal was completed in 1994, and the first migrants arrived to Luanjingtan shortly after that. According to our driver, the area in which Luanjingtan town is located was once used for grazing.

Today the town is home to more than 6000 ecological migrants from 87 different villages and smaller locations, some of them having moved from a distance of more than 700 kilometres away. About 15-16 per cent of herders in the Alxa region were relocated to Luanjingtan. Although the majority of residents are ecological migrants, some have been resettled from the nearby Helan Mountains by the government to make way for a dam project, and a small number are so-called "economic" migrants from Gansu and Ningxia provinces who have bought farmland in Luanjingtan and remained.

While the Yellow River supplies water for farming, groundwater is the source of the local drinking water. The town is serviced by an all-season paved road, and many residents have internet access. In addition the town offers a healthcare facility, a school, numerous shops, several restaurants, a government department, and a hotel. Some residents have two homes, one located on or close to their farmland, and a smaller apartment or home in the center of the town. The main crops sown are corn, sunflower and water melon. Most families also keep several goats and/or sheep as well as chickens for own consumption, and plant vegetables, including tomatoes and chillies, also for household consumption. Several of the interviewed households also raise livestock for the market under controlled grazing and feeding schemes. As in Bantanjing, goats and sheep for private consumption are stall-fed. Agricultural fields are bunded on all sides and many are planted with poplar trees to lessen erosion and wind damage. The majority of trees were planted along the borders of farmers' fields between 1993 and 1997.

Residents of Luanjingtan pay a fee for irrigation water. The fee includes a small unit price for the water, and a larger unit price for the electricity needed to pump the water from the canals into individual farmers' fields. Before 2003, the total unit price was .193 Yuan per cubic meter. After 2003, the price has been around .264 Yuan per cubic meter.

Interviews in Luanjingtan took place in two "smaller villages" (gacha) within Launjingtan. The first village, called *Taatu*, is home to 128 families, of which about 10 are ethnic Mongolian. We were not able to interview any of the Mongolian households however as we were told that most of them do not work in the village and on that particular day they were looking for off-farm jobs outside of Luanjingtan town. The second village is called *Hubuqi* (pronounced Hubutsi), and is home to 110 families. The first emigrants in both villages arrived 14 years ago, right after the

[21] 1 stere = 1000 liters.

canal system bringing water from the Yellow River was completed. Construction of the canal system lasted from 1991-1993/4. Hubuqi village was established in 1994. At that time, 87 families moved to Luan Jing Tan. About 55 of these were from the same village in the Tengger desert. Approximately 15 of these families subsequently moved away. An additional 23 families moved from the neighbouring provinces of Ningxia and Gansu. These 23 families were not ecological migrants, but people who decided to move in, bought farmland, and settled down (so-called "economic migrants"). According to the village head these migrants arrived gradually, at a pace of about 2-3 families per year after 1994. About 10 per cent of the village population is Mongolian.

4.6.4 Government compensation, assistance and incentives

4.6.4.1 Bantanjing

The original migrants to Bantanjing did not benefit from the services and compensation afforded to later waves of migrants. They received little government support, and according to long-time residents life was very hard as there were few services in the village at that time. They built their homes themselves, and there was no road, telecommunications, medical facilities, or electricity. Migrants who resettled after 2000 receive compensation under additional government policies connected to conversion of marginal farmland to grassland and forest under the government's Grain for Green programme (Brogaard and Seaquist, 2005; Du, 2006) that compensates migrants with food grain in exchange for conversion of their original farmland to grassland through natural re-vegetation), or "forest/shrub land" (assisted land conversion)[22]. The compensation received varies according to the policies in the regions from which migrants moved, and the rules governing the type of land they occupied. For example, families who moved to Bantanjing after 1998 were contracted free land for personal use, or leasing to others, received free or subsidised housing, government-financed paddocks for livestock, and technical training in agricultural and livestock rearing methods. An old-age supplement is also provided by the government to households with women of 50 years or older and men of 55 and older.

4.6.4.2 Luanjingtan

Government assistance for migrants who moved in 1994 when the town was first established was more limited back then than it is today. Those interviewed who moved to Luanjingtan at that time did not receive a free house or financial compensation, but they were given farm land for free (a total of 12 mu [23]) per person for families of 5 or less, and 60 mu total for families of more than 5). People paid between 30 and 50 Yuan per mu to have the land cleared and ploughed for farming by the government. Although they did not receive compensation for their original land from the government, the village from which they moved had some money that was held collectively, and some of this money was divided up among the migrants, with each receiving between 200 and 400 Yuan as a one-time payment for moving.

Village residents lived in tents or in simple earth dugouts when they first arrived. They built everything (houses and stalls for their animals) themselves with help from one another. The road was not properly constructed. During group discussions in Taatu and Hubuqi, people often

[22] For a description of these policies see Du, 2006, Dickinson and Webber, 2007 and Runhong, 2001.

[232323] 1 mu = 666,67 m²

noted that the compensation for later waves of migrants had improved compared to when they moved. This was regardless of when they moved: those who moved in 1994 noted that those who moved after 1998 received more compensation. However those who had moved to the village in 2000 also said that later migrants received better housing, and better compensation.

Agricultural training – including in crop production and small livestock breeding – is provided to all residents. Villagers in Hubuqi notes that training provided when they first moved was very simple, but it is now offered on a yearly basis. Several households in Hubuqi mentioned that they had learned farming techniques from their neighbours who included economic migrants from Gansu and Ningxia provinces. Residents of Hubuqi also noted that government agricultural assistance such as subsidies on seeds and diesel for tractors had improved in recent years.

Electricity is now provided to all households. However, in 1994 the only option was wind power, and only wealthier families were able to invest in wind turbines to produce electricity for their own needs.

In general, most households that were interviewed were happy with the assistance provided by the government. However, a number of concerns connected to the policy and the compensation provided were raised. These are summarised briefly below:

1) The policy has changed over time and become more comprehensive with more lucrative compensation (free farmland, housing, and shelters for livestock, in addition to monetary compensation) given to the most recent migrants, compared to those who migrated earlier. Unequal compensation is viewed to be unfair to those who were the first to move to the new settlements and who faced harsh and demanding living conditions with few services and little, if any, government compensation. Implementation of current compensation schemes also varies according to local criteria and where migrants moved from.
2) Ecological migration is closely connected to government policies of grassland rehabilitation and to payments for land reclamation and forest plantations. There is a possibility that local people may not have been properly informed of the goal of government grassland, ecological migration, and forest policies, which have been conceived, implemented and scaled up rapidly over a very short period of time (see e.g. Runhong, 2001). The fact that these policies are not easily distinguished from one another in peoples' minds may make it difficult to understand why some people receive different compensation than others.
3) Migrants' expectations of the outcome of the policy for their livelihoods were not always fulfilled. Several households mentioned that they "thought they would get rich" as a result of migrating. However, many people reported that there income had not changed since moving; while at the same time they had become 'busier'. A number of households mentioned limited non-farm income earning opportunities. Some people also mentioned that living and farming in the new villages was more expensive due to high costs of water and electricity for farming, and the high cost of store-bought food and household goods and supplies. Several of those interviewed in Luanjingtan lamented the dependence on middle men for selling agricultural produce.
4) Several households noted that the grazing areas from which they had moved had improved considerably, and said that they would like to be able to graze animals again, if the vegetation continued to recover.

5) Several households mentioned loss of freedom over decisions about their lives and income as being of concern, raising concerns about the degree to which migration was actually voluntary.
6) Several key services in the villages were considered to be sub-standard and of need of improvement. In Bantanjing the main concern was inadequate provision of, and high costs of, electricity for household and farming needs. In Luanjingtan a lack of irrigation water was a key concern. The problem was attributed to the uncontrolled influx of migrants and expansion of farmland in recent years coinciding with a hot, dry summer and reduced rainfall in 2007, and poorly dimensioned irrigation canals. The quality of drinking water (sourced from groundwater) in the village was another key concern. It was said to contain too much fluoride, have a sour taste, and contain residues.
7) Several households voiced concern about the ability of the government to continue to finance the various forms of compensation provided to residents, and a few indicated that they would leave the villages if compensation was discontinued. Most however said that they had no land to return to in any case and that they had family and friends in the village now. Elderly households noted their poor health and aging as a barrier to moving again and "starting all over".

4.6.5 Reasons for moving

The main reasons given by those interviewed for why they migrated were 1) the government policies, including the ban on grazing, as well as incentives and compensation offered by the government for moving, such as free housing and agricultural land for those who chose to move, 2) degraded grasslands and, 3) reduced incomes and/or poverty connected to degrading grasslands. For almost all migrants who moved to Bantanjing before 2001, the move seems to have been immediately precipitated by a drought event. Those who moved after 2001 tend to have been those who also benefited from the Grain for Green policy. In Luanjingtan migrants moved for a variety of reasons including land degradation in their home regions, resettlement to make way for a dam project in the Helan mountains, and for economic reasons.

It is therefore difficult to draw generalisations about migrants' motivations for moving from their homes. Migrations in Bantanjing span nearly 3 decades, and in Luanjingtan, 15 years, and policies and compensation schemes have evolved and changed over the years. There are also clear indications of local variations in the ways in which the policy was implemented even for migrants who moved at the same time. Moreover, different waves of migrants came from different areas, and were affected to varying degrees by environmental degradation depending on the location of their original homelands.

Motivations, expectations, and the freedom to choose whether or not to migrate seem also to have also varied according to whether one migrated several decades ago, or more recently. Peoples' expectations for what is needed for a "good life" has also changed, concomitant it seems with the move into larger villages that has led to better connectivity with the outside world and markets, and more convenient access to greater diversity of services and goods for migrants, as well as new ideas and training.

While some households that were interviewed clearly felt that they had no other option than to move due to the severe environmental degradation and their own poverty, others simply said that they moved because "that is the government policy". Others still – typically younger migrants – said that they were motivated by curiosity about "life outside the desert", and a desire to do something new.

4.6.6 Perceptions and experiences of environmental and climate variability and change

4.6.6.1 Bantanjing

According to long-time residents and migrants from nearby villages, up until the 1970s, the climate in the Bantanjing region was stable, and there was enough rain and good quality grassland to enable grazing by many livestock. Residents explained that there was a severe drought in 1983-84 during which time almost no rain fell. Many animals died during that period and herders' livelihoods were strained. A prolonged dry spell occurred again in 1998, lasting for several years. After this second dry spell, many herders were no longer able to continue their traditional livelihoods, and migrated into government sponsored townships.

Residents noted that sand storms have become stronger in intensity in recent years, especially since 1998. The sand that is deposited on cropland ruins its texture and makes it unsuitable for growing crops. Some people noted that there is generally less precipitation, and others noted that the winters are becoming warmer. 2007 was, however, an anomalous cold year during which residents noted that the town water pipes froze and burst. According to the retired village head, 2007 was the coldest winter he can remember.

4.6.6.2 Luanjingtan

According to local officials, before the 1950s, vegetation in the Luanjingtan region was very good, but after the 1950's it gradually became degraded due to decreasing rainfall and increasing livestock numbers. A local official told us that the growing season for Malian (a purple flower that is native to the Alxa region) starts 2 weeks earlier than it used to, and certain plants grow only about a third as tall as they once did. Many people felt that the local environment in and around Luanjingtan had been much improved as a result of the irrigation from the canal system and extensive efforts at planting trees. Some also noted that the vegetation in the surrounding countryside had recovered to an extent and that the government had started enacting private grazing right to certain households. People who had moved from far away and near the deserts said that the climate in Luanjingtan (near the foot of the HeLan mountains), was better suited for agriculture than where they used to live. Others who had been relocated from the Helan Mountains due to a planned dam project lamented the more lush vegetation, better climate and clean water that characterised their former homes.

Residents of Taatu noted that there were no trees in the town when people first began to move, and according to local people, there were a lot of sandstorms and strong winds back then. One woman from Taatu joked that the kitchen was outside at that time, so when you drank a cup of tea, half of it was sand. The winds have reduced in frequency and severity in recent years, and residents felt it was because of the planting efforts (in particular tree planting) around the town.

Last summer (2007) was particularly dry, and there were serious water shortages for irrigation in the town. Normally during the summer (from June until August) crops are irrigated every 15 days. However, due to shortages last summer farmers went up to 30 days without irrigating their crops. The reason for the shortages was contested. The main reason cited was that more and more people are living in the town due to uncontrolled population growth. There has been a subsequent increase in agricultural area, with no change in the dimensions of the irrigation facilities. Several people also mentioned that there was less water in the Yellow River due to lack of rain; that the distributing channels for irrigation are too narrow, and that water may have been diverted to Ningxia for other purposes, reducing the total volume supplied.

Reasons for degradation

When asked about the reasons for degradation of grasslands in their homelands, migrants mentioned climatic variation (reduced precipitation and warmer winters, combined with more and/or worsening sand storms and stronger winds), as well as increasing stock numbers due to general government reforms implemented after 1978 that encouraged private livestock ownership (see Brogaard and Seaquist, 2005, for a discussion of these reforms).

4.6.7 Livelihood impacts and new livelihood challenges in migrant towns

4.6.7.1 Livelihood impacts

General livelihood improvements reported across the villages included better access to healthcare (Bantanjing and Luanjingtan), and electricity and education (Luanjingtan), more friends and neighbours (both villages), more diverse diets due to cultivation of vegetables (both places), and better connectivity due to mobile phone coverage and roads (both places). While some residents noted that their incomes had improved, others maintained that they were about the same as before. However, a number of former herders commented that they were "busier" than before, which could mean that the proportional effort required to earn an income equal to herding as a farmer is greater. The increased effort could also be related to some villagers' commitments to plant and maintain non-agricultural vegetation on lands falling under the Grain for Green policy.

Bantanjing

Almost all respondents noted that their lives have improved in several ways since moving to Bantanjing. The most consistently reported improvements were in access to healthcare, roads and services, and more vegetables in the family diet. Long-time residents reported the greatest improvements in their living conditions. Villagers explained that the services and infrastructure in the village had improved over the years as more migrants settled and government investments were intensified, particularly after 1998 when the village was designated as a model demonstration area by the government. The high cost of operating oil generators for household use and to fuel bore well pumps for irrigation, and lack of universal electricity service among households was the main concern highlighted over and over by residents during interviews and in the group discussion. Some residents mentioned that they pool their resources to buy diesel and transport it back to the village from larger centres. But the added cost of transport makes this even more expensive. The lack of a school in the village was mentioned as a concern for households with children of school age.

Luanjingtan

According to the host of our visit, a local official, residents enjoy living in Luanjingtan because people who were once isolated and living far from hospitals, medical services, schools, and roads, now have access to all of these services, and can even connect on the internet and chat to the wider world. All of the people who we interviewed noted improvements in their lives since moving to Luanjingtan, including access to a wider variety of goods and services, proximity to markets, a good road, healthcare services and schooling, and more friends and neighbours.

4.6.7.2 New livelihood challenges

Not all of those interviewed reported improvements in all aspects of their livelihoods. Perceptions were especially ambiguous when it came to income. While people of poorer households said that their income had not changed since moving to the villages and lamented a combination of high costs of farming, poor health, and/or a lack of economic opportunities, wealthier households usually said that their incomes had improved. These households typically had diversified from farming, to farming in combination with growing medicinal plants (Bantanjing), or purchasing farming equipment and enlarging their land holdings (Luanjingtan). Households also depended to different degrees on non-farm income. Several households had become indebted by either renting or purchasing additional land to try to increase their income, and subsequently suffered poor harvests and health care obligations that made it difficult to pay back the debt. This was the case in two interviews with elderly households where the principle residents were age 55 and over (one in Bantanjing and one in Luanjingtan).

Most residents of the village were herders, or herders and farmers, by tradition, before moving to Bantanjing, and for some, the transition to farming has not been as straightforward as for others. Ethnic Mongolian migrants raised specific concerns about the difficulty in adjusting to a new way of life as farmers due to a lack of farming skills. Comments such as "farming is based on experience", "we are bad farmers" and "we know only herding", though communicated in a jovial way often accompanied by laughter, seemed to underscore the fact that the transition from herding to farming was not an easy one for people whose identities and culture are closely tied up with herding animals, and highlighted that some residents feel "out of place" as farmers. Some respondents noted that they missed eating goat meat, that it was easier to get, keep and eat livestock before, and that they would like to be able to graze their animals again in the future if the grassland continued to improve and the climate was not too bad, government policy permitting. Comments were also made about missing one's home, the wide open space, quiet, and "freedom" to choose one's activities before as compared to in the villages.

Agricultural training provided by the government aims to minimize the challenges that migrants face. However, a lively discussion in one household revealed that the government agricultural training was offered in Chinese, with no translation or instruction available in the Mongolian language. According to respondents, this language difficulty made it more difficult for herders to understand the farming instruction and demonstrations. In addition, one Mongolian household raised concerns about uneven economic development and opportunities in the village due to different levels of government compensation and access to off- and non-farm income.

During interviews in Luanjingtan, several households noted that it was more expensive to farm in the town compared to the place they had moved from due to the high cost of the water, fertilisers, and pesticides. According to other residents, the price of water paid by farmers is not a concern, but rather it is the total available amount of irrigation water and its timing that is of importance for farmers. In Luanjingtan several migrants noted that they have no choice but to sell to the middlemen from Ningxia who come to buy up their produce. The suggestion was made to build a mill to add value to the town's agricultural produce so as to cut out the middle men and increase farmers' income. In discussions with our host later during lunch we were told that this possibility was being discussed at higher levels of government. It has therefore likely been a topic of local meetings and discussions.

4.6.8 Climate adaptation and sustainability challenges

Table 1 summarises the adaptation actions that interviewees mentioned when they were asked to explain how they were responding to the climate-related challenges to agricultural livelihoods.

Table 1: Summary of climate adaptation challenges in the agricultural sector in the villages.

	Bantanjing	Luanjingtan
Climatic changes experienced	Stronger winds and more frequent sand storms since 1998	Dry summers contributing to irrigation water shortage (e.g. 2007)
Adaptations employed	i) Construct live wind barriers by planting trees; Erect "wind fences" ahead of forecasted wind/sand storms ii) Rely on government compensation for food crops damaged by extreme weather iii) Switch to crops that can tolerate more sand – such as wheat, and less water, such as *Suo Sua* iv) Diversify livelihoods	i) Plant more watermelon (less water demanding) ii) Rely on weather reports for planting iii) Call on government to increase dimensions of the irrigation channels, limit expansion of farm land and introduced water-saving techniques
Outcomes and implications	i) Reduced erosion of top soil and reduced deposition of sand on agricultural land ii) Cash crops such as sunflower and cotton are not covered by compensation iii) Wheat not planted on a large scale. iv) Growing medicinal plants (*Suo Sua*) increases HH income for some. Labour shortages for agricultural work in other households where members migrate seasonally for non-farm work	i) Planting winter wheat no longer possible due to lack of irrigation water in Winter. All crops must be planted in the Summer. ii) These are short-term (i.e. not climate forecasts) and are not always accurate. If you make the wrong choice in terms of crops sown, and the rains fail, you will be in trouble. iii) The government is working on solving these challenges. Ban on emigration recently introduced, distribution channels are being improved (from mud to concrete) to limit leakages, and drip irrigation techniques are being piloted.

4.6.8.1 New sustainability challenges

Bantanjing

As mentioned previously, the source of irrigation water for farmland in Bantanjing village is groundwater accessed via bore wells. Although irrigated agriculture is certainly an adaptation to an arid climate, the pumps for the bore wells run on diesel, and residents noted that the high price of oil had increased farming costs, rendering agricultural incomes more vulnerable to crop failure. It is possible that groundwater tables could also be depleted in the future if water extraction for agriculture, shelterbelts, and household use in the village exceeds natural regeneration rates. Increasing temperatures may increase irrigation water needs of different crops, leading to more rapid depletion of ground water. This would introduce additional limits on agricultural production and incomes.

In terms of mitigation and local energy solutions, solar panels were constructed and installed under a Japanese bilateral aid project between 2002 and 2007. They were designed to supply electricity to the entire town. However, during interviews I was told that the panels do not work properly, break down frequently, and require expensive repairs and replacement parts. Maintaining the panels is difficult since replacement parts must be obtained and transported from far away. Local generators owned by some private households, as well as irrigation pumps in the village, run on diesel, and concerns about the cost of electricity generation and lack of electricity in the village were repeatedly raised during interviews and group discussions.

The community's peripheral location and distance from markets can be seen as obstacles to adaptation in the sense that goods and services are more difficult and costly to obtain, and people must travel far to obtain alternative employment and to sell their agricultural produce and purchase inputs and supplies. However, as mentioned, the main road to the village is currently being upgraded and is designated to become a paved highway, which should lessen these challenges to a degree.

The climatic and other challenges associated with farming in Luanjingtan have led some families to abandon agriculture to find another living in the strongly developing industries or in larger urban centres as a type of livelihood adaptation. Luanjingtan is relatively close to Ningxia province and is connected to the capital, Yinchuan, by all-season, paved roads.

Luanjingtan

A main concern among all people interviewed was with water for both farmland and household use. The quantity of water coming from the river is not enough to meet the demands of all the farmland in the village and has gradually become a bigger problem as more and more people have moved to the region. Water supply from the Yellow River may be further reduced in the future due to rising temperatures and increasing incidence and duration of droughts, in combination from growing demands for water upstream for rapidly developing industries and agriculture in Ningxia.

A second concern raised by respondents is the quality of the groundwater, which is used for household use. According to local officials and residents, the groundwater table in the Luanjingtan area is actually rising due to infiltration (leakage) from the canal systems and excess irrigation in farmers' fields. This could be contributing to some of the quality problems.

Thirdly, a number of residents highlighted the need for more varied livelihood and income opportunities. This would enhance their well-being and flexibility to cope with shocks such as extreme weather and drought that affect crop production. One suggestion was to construct a mill or factory for processing agricultural products in the town. This would cut out the middle men who buy up farmers' products and give farmers a better price for their produce, and create additional income and employment possibilities for residents.

4.6.8.2 Responsibility for adaptation

When asked about what was being done to reduce their vulnerability to climate variations, events and impacts, most people, implicitly or explicitly referred to government policies, support and compensation. For example, in 2007, the government introduced a compensation plan for residents of Bantanjing for agricultural crops damaged or destroyed due to land degradation and severe weather, especially sand storms. The policy compensates villagers for loss of or damage to food crops, such as maize, but so far it does not apply to cash crops such as cotton and sunflower. Villagers are also encouraged to plant trees on the boundaries of their farmland, in addition to bunding, to prevent erosion, and they explained that they have learned to erect temporary grass/stick fences ahead of storms to shield their crops from wind and sand, to lessen damages.

Other comments such as "We can't foresee the weather, we hope it will be okay" and "It's the responsibility of the government to make the correct policies" suggest that respondents feel they have little control over or ability to control their vulnerability to climate change. This seems to parallel the lack of control over their own lives and livelihood decisions that migrants experienced during the transition from herding, to farming.

In Luanjingtan, when asked what could be done to solve the problem of irrigation water shortages such as that experienced in the Summer of 2007, residents said that there is only so much farmers can do to conserve water, but that the main responsibility for dealing with shortages, rests with government policies and development and dissemination of technological innovations.

Interestingly, when policy-makers in Alxa League were asked to discuss how they were dealing with the new sustainability challenges in ecological migrant villages (such as electricity and water shortage), they said that it is far easier to "control" the problems created when people are living in migrant towns. This is in contrast to before when herders lived spread out over large geographical areas, and who, according to one official, could destroy large tracts of land because they operated beyond the government's control (ADAM IM workshop 2009 summary, pending). Officials see migrant villages as opportunities to rapidly deploy and "scale up" technological innovations such as water-saving irrigation techniques, and they felt confident that any new environmental problems arising from the movement of large numbers of people to migrant villages and towns could be easily detected and dealt with. They also noted that education and awareness raising among residents about climate and environmental changes is much easier when people are living in the villages (ibid).

4.6.9 Conclusions

To various extents, migrants in Bantanjing and Luanjingtan see the policy of ecological migration as an adaptation to a situation in which vegetation and grasslands had degraded to a point beyond which land-based livelihoods could no longer be sustained. Reasons given by those interviewed for migrating to these settlements had to do with both environmental conditions (limiting, or "push" factors), and in the case of more recent migrants, the existence of attractive government assistance and compensation for families willing to move, through policies and programmes connected to both ecological migration (free housing, farmland and training), and compensation provided under the "grain for green" and forest and grassland rehabilitation projects, as well as general economic development and poverty alleviation strategies (what can collectively be called "pull factors" or incentives).

However, it is difficult to generalise from the data about the relative importance of factors contributing to households' migration, or the degree of control and choice they had over the process of ecological migration. This is because of the long time period over which migrations to Bantanjing and Luanjingtan have occurred and the evolution of government policies over this time, the difference in the geographic locations of migrants' original homes (ranging from 10 to 700 km away), and the relative environmental degradation experienced in those locations, as well as local variations in the ways in which current policies have been implemented.

While many interviewees who migrated or were resettled into ecological migrant towns feel that their lives have improved in key areas such as access to healthcare and schooling for their children and access to more goods and services, challenges associated with ensuring that the move is a sustainable one in the longer term remain. These include ensuring adequate and inexpensive access to clean forms of electricity, providing adequate water for irrigation, ensuring adequate quality of water for drinking and household use, ensuring a range of employment and income activities, and providing culturally appropriate training to facilitate sustainable transitions from livelihoods based on herding, to those based primarily on farming. Several of the households that were interviewed noted that some families who originally migrated together with them (from the same village or region) had left the new settlements. This indicates that there has also been dissatisfaction and unmet expectations during the process of ecological migration for some households. Indeed, although many people noted that there lives had improved in terms of access to some services, few reported that there incomes had improved, and many emphasised that they were 'busier' than before, which can be taken to mean that more effort is required to obtain the same income in farming compared to herding.

Vulnerability and adaptation to climate change

Residents of ecological migrant towns have to various extents chosen migration as a way of dealing with vulnerability in their former livelihoods caused by among others, climate variability and desertification, rapid economic and social changes, and evolving government policies governing degraded grasslands. Livelihood adaptations resulting from ecological migration, expressed in the transition to farming, raise both new climate adaptation, as well as mitigation issues. An example of the former is irrigation water shortages during droughts in Luanjingtan, and reliance on expensive oil and partially functioning wind-based electricity generators to fuel bore well pumps for irrigation and household drinking water in Bantanjing. Climate change adaptation concerns for agriculture in the new villages include whether crops and irrigation systems are sufficiently adaptive to withstand projected climate variations and extremes, including whether the extraction of groundwater for irrigation and household use in the new villages is sustainable.

Perhaps the most pervasive constraint to successful adaptation in the new villages in the long run is related to local people's perceptions of the government and its policies as offering the main and most important solutions to the problems associated with ecological degradation, poverty reduction and climate change adaptation in the migrant villages. While government policies are certainly important and can arguably provide stimulus and support for successful adaptation at the local level, there was very little awareness among those interviewed about what they themselves, either as individuals or communities, could do to adapt to long-term climate and environmental change, government policies and support not withstanding, despite high awareness and much personal experience of the effects of desertification and degradation in their homelands. This complacency must certainly be understood in connection with and as a partial product of, the wider context of the transition from herding livestock on grasslands, to farming in government-sponsored migrant villages, as a way of life, during which migrants experienced a certain loss of control over decision-making, a loss that many exchanged for promises of a better life, and a brighter future, in the migrant villages.

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4.6.10 References

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Appendix: Interview Guide – Alxa League field visit 13-19 November, 2008

Introduce myself, Li Shan and explain the goals of the fieldwork and what the information will be used for. Explain that respondents' names will neither be recorded nor used in any written material. Explain the fee that we will pay them to thank them for their time (100 Yuan).

General questions

1. How old are you?
2. How many people live in your household, and what are the ages of the family members who live with you?
3. From where did you move? How far away? When? For how long did you live in that place (before?)
4. For how long have you lived here?
5. What did you and your family do to earn a living before you moved?
6. What do you and your family do to earn a living now?

	Person interviewed	Husband/wife	Other
Jobs/ income where they live now			
Jobs/income where the lived before			

7a. Why did you move (spend some time on this question)?
8a. Did you get help to move?
8b. If yes, what kind of help did you get?
8c. If yes, where you happy with the help you received?

Changes experienced by the interviewee

9a. What was life like for you (and your family) where you lived before (focus on social, economic, and environmental aspects)
9b. Were there any good things about where you lived before?
9c. Were there any bad things/things you didn't like about where you lived before?

Since you moved

10. Has your life changed since you moved? If yes, how?
11. Are there things that are better now for you and your family? What things? Are the changes because of moving, or other reasons?
12. Are there things that are worse (better translated as 'didn't meet your expectations') now for you and your family? Are the changes because of moving or other reasons?

Changes in (please tick and mark 'better', 'same' or 'worse')

	Health	Food	Income	Water	Economic activities/ income	Education	Social life	Other
Interviewee								
Family								

Comments:

Views on policy of ecological migration

14. Is it a good policy? Why or why not?
15. Overall, are you glad you moved? Please explain
16. Could the policy be improved? How? (*this question was later supplemented with ' How can your life be improved here?*)
17. If government support was discontinued, would you still choose to live here (*asked to about half of respondents*)

Climate variability and change

18. What was the climate/weather like where you lived before?
19. Did you notice any changes in the climate/weather before you moved?
20. Have you noticed any changes in the climate/weather since you moved here?

Explain/discuss (*e.g. more/less rain? More/less sandstorms? Other?)*

Group discussions *(in addition to questions above)*:

21. Tell me a bit about the history of this village/town (*e.g. when did people move here, crops grown, infrastructure, changes experienced, and other follow-up questions*)
22. What can or is being done to adapt to climate variability/ unpredictability?
23. What kind of changes could improve the lives of local people/residents?
24. Various other questions according to the situation

4.7 Coping with climate impacts & desertification: results of a survey questionnaire

H. Neufeldt and G. Jia

4.7.1 Introduction

Over centuries, the population of Inner Mongolia has coped with the extremes of a temperate steppe and desert environment. The traditional nomadic pastoralism was well adapted to the icy winters, hot summers and very low and erratic precipitation. Today most Inner Mongolians are sedentary, following the immigration of Han Chinese after the establishment of the Republic of China and in particular since post-revolutionary policies (Dickinson and Webber, 2007). Since then, many Mongols have taken up agricultural land use and most herders have abandoned rotational grazing practices.

The combination of population growth, agricultural intensification and overgrazing, together with naturally vulnerable endowments have led to extensive land degradation and expansion of desserts. According to Jia et al. (Section 4.2) 65% of rangeland in Alxa is degraded and productivity has fallen by 25% over the past 20 years. In addition to high natural climate variability, climate change is likely to add additional stress on the environment. Temperature is showing a strong warming trend since the 1970s, and regional climate models predict a further rise, ranging from 4.4 to 5.2 °C and from 3.4 to 4.0 °C above preindustrial values by 2100 for the A2 and B2 IPCC SRES scenarios, respectively (Xu et al., 2006; Dai et al., 2008). A first survey questionnaire carried out in Alxa indicated that approximately 60% of respondents made a connection between climate change and extreme events, such as the increasing number of dust storms (Dai et al., 2008). But there is as yet insufficient understanding of how climate change is perceived, what kind of impacts are expected and whether climate change is seen as a threat to future development and wellbeing.

As a means to counter rangeland degradation, central Chinese government has in the past few years introduced a series of environmental and social policies and measures such as restricted grazing (total ban; rotational grazing), wind breaks (e.g. hedging of desert expansion through tree shelterbelts), artificial precipitation, poverty alleviation and herder resettlement programs (Werners et al., 2010). Where applied, restricted grazing has led to some rangeland recovery (Jia et al., 2009), and the so-called ecological migration policy has resulted in the resettlement of approximately 25,000 herders in five years (Du and Huang, 2005). But little information is so far available on the perceived effectiveness and acceptance of these policies and measures.

Through a survey questionnaire that was carried out in all three banners of Alxa league[24], we recorded perceptions of climate change related impacts, attitudes towards environmental policies and measures and expectations of future developments. We also tried to shed more light on the capabilities to cope with climate related risks, possible barriers to raising adaptive capacities and the willingness to pay for protection against extreme weather events. This information will be useful to stakeholders and policy makers in developing more adaptive policies and measures.

4.7.2 Materials and Methods

The survey questionnaire was carried out between 18 October and 1 November 2008 in 23 settlements of all three Alxa banners: Ejina Qi, Ayou Qi, Azuo Qi (Figure 4.35). The surveys were carried out by research assistants in the settlements. In total 98 questionnaires were filled out. The questionnaire was mostly based on multiple-choice or ranking questions, but required a few open answers as well. It addressed issues ranging from assessment of livelihoods, assessment of current and past environmental problems, evaluation of existing policies and measures and expectations for the future. The questionnaire consisted of 42 different questions, several with a number of options or follow-up questions (see Annex I for the total list of questions). However, only selected questions were analysed for this paper.

The number of respondents was high enough to show clear trends, which were subsequently analysed statistically with SPSS software (SPSS, 2007). For the analysis only trends and ranges of magnitude, but no absolute figures were used. The data set showed some irregularities:

- It could be shown that several respondents coming from the same township had responded identically to some questions. Where this was apparent, the responses were manually excluded from the analysis. For instance, there were 7 teachers in the whole data set, who all came from the same township. By their answers to the open questions it became apparent that they were responding to the questionnaire together and even ensured consistency between themselves. Their responses were excluded from the analysis.

[24] Leagues and banners are prefectural-level and county-level administrative units, respectively.

- Another limiting factor was that questions were often not understood as expected, possibly due to inaccuracies during the translation process. For example, cross-examining income with the ability to obtain bank loans indicated that richer people apparently had less access to bank loans. More likely, the question was understood in the sense that people required or requested bank loans. This would be less likely for those who have better income.

The analysis of results is therefore hampered by factors that often cannot be fully understood. In order to reduce interpretation of pseudo-significant results, only where a clear connection between independent variable and result could be established was the information interpreted. While this procedure cannot eliminate errors, it does allow to draw certain conclusions on trends that could be verified at a later stage where necessary.

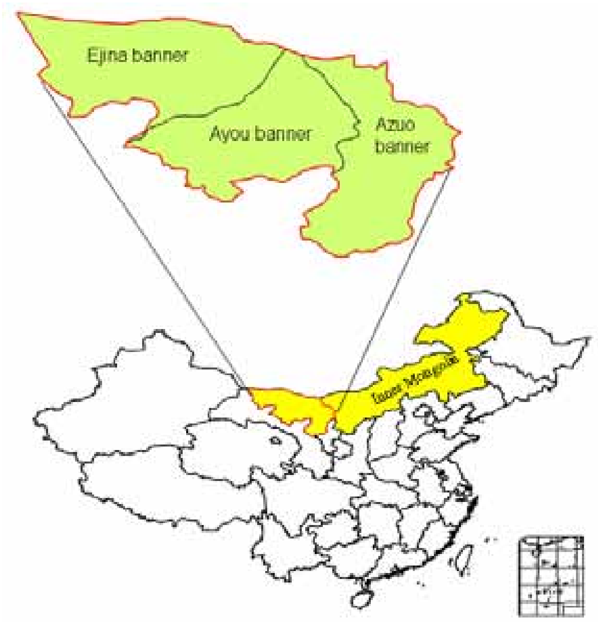

Figure 4.35: Map of Alxa league and its three banners (counties).

The data sets were first analysed for frequencies, which provided information on the mean, median and standard deviation of aggregated variables as well as on the number and percentage of responses for a given set of independent grouping variables (see below). The responses were then analysed by means of one-way ANOVA to identify significant differences of any independent variable for the whole data set. This analysis included a test for normality of the underlying sample. The Tukey-HSD test was used to study significance of differences between the groups for any independent variable. Multi-factorial analyses, e.g. to study the statistical differences of an independent variable as a subset of another independent variable, were not carried out.

Five independent grouping variables were used to analyse the data set for trends:

- **Gender**: 76% of the respondents were male and 24% were female. Although the gender balance was not good, in statistical terms the underlying distribution was normal.
- **Counties**: The regional distribution of the respondents was analysed based on the county (Qi) they came from. The three counties reflect an East to West transect which is

consistent with precipitation decreasing from 200mm in the South-East to only 40mm in the far West (Dai et al., 2008). However, an in-depth analysis showed that none of the farmers lived in the western counties. This grouping variable was therefore excluded from the analysis.

- **Type of settlement**: Four categories of settlements were distinguished. 12% of respondents came from towns, 43% from villages, 27% from isolated farms and 18% from 'eco-migration settlements[25]. The respondents were free to characterise their type of settlement, which led to a certain degree of overlap such that a place identified as a village by one may have been categorised as eco-migration settlement by another. The main rationale behind distinguishing between these four categories was to test whether people living in towns or villages were more resilient or less exposed to climate impacts than inhabitants of isolated farms. It would possibly also show some less predictable outcomes, for example between the populations of eco-migration villages and other villages.
- **Level of education**: Four levels of education were distinguished ranging from primary to university level. 28% of respondents only had primary education, 38% had secondary education, 22% had completed high school and 12% of respondents had visited university. This category, like the previous one, is expected to reflect resilience or exposure to climate-related impacts, but might also show interesting trends regarding perceptions to climate change or policies.
- **Occupation**: Five different occupation categories were identified. However, only farmers (37%) and herders (48%) were analysed statistically, since there were too few respondents from business (3%), government (5%) or others (7%; all teachers). Between the two main groups the focus was to study different perceptions regarding climate impacts and policies.

4.7.3 Results

4.7.3.1 Personal information

The respondents were on average 41 ± 7 years of age, lived in families with 3.7 ± 0.9 members, had 1.6 ± 0.7 children and earned ¥ 33,900 ± 18,700 per year (approximately € 4000). These relations were not significantly different between the grouping variables except that income of those with university degree was significantly higher than that of all other education levels.

Figure 4.36 shows the distribution of expenses for the total sample as well as for farmers and herders. On average, housing, electricity and heating together added up to about 15% of total expenses. Food required another 15% of total income. Living costs, which include clothing, communication, transportation, medical and other costs, added up to 22%. Broadly the second half of total income was divided into production costs (29%) and education (18%).

[25] Eco-migration villages are comparatively new settlements to which primarily herders have moved within an environmentally inspired resettlement program to reduce grazing pressure on the vulnerable steppe ecosystem (Du, 2006).

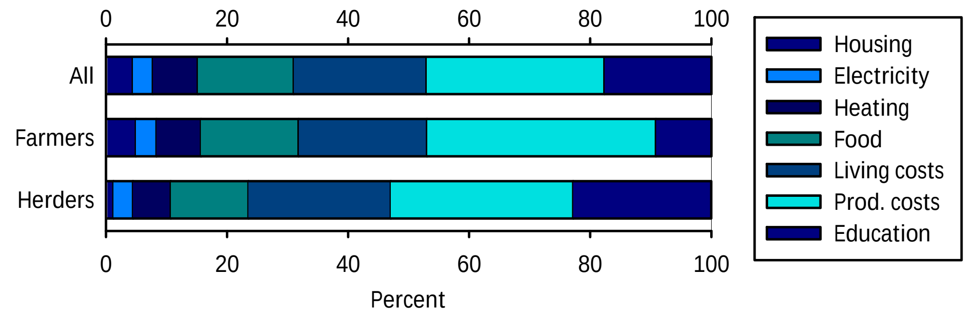

Figure 4.36: Distribution of expenses for all respondents and differentiated for farmers and herders.

With ¥ 29,500 ± 10,300 and ¥ 32,200 ± 15,900, respectively, income of farmers and herders was a little below average. Although herders had a slightly higher average income than farmers, differences were insignificant. This finding was confirmed by the participants of a stakeholder workshop in Alxa in May 2009 (West, personal communication). Comparing the expense distribution between farmers and herders revealed farmers' costs for housing, electricity, heating and food to be similar to the average, whereas herders spent considerably less on these items. This may be related to the more self-sufficient and considerably more isolated lifestyles of herders (Table 4.8). Living costs were comparable for both farmers and herders, but there were great differences in production costs and expenses for education. Farmers spent much more on production costs, possibly because seeds, fertilizers and machinery are more costly than raising livestock, but on the other hand herders spent more than twice as much on education. This might have to do with generally greater distance to schools, but cannot be answered conclusively.

Table 4.8: Distribution of settlement types between farmers and herders.

Settlement	Farmer	Herder
Town	0%	2%
Village	83%	21%
Isolated	3%	49%
Ecomig	14%	28%

4.7.3.2 Environmental problems and climate change

Climate change is perceived to be a major problem. Over 90% of respondents have heard of it (Figure 4.37) and of those 97% believed that it will have impacts. A clear majority associated climate change with reduced yields and changing precipitation patterns, but less than 40% related rising temperatures to climate change. Respondents with university degree tended to know more about the temperature effects of climate change, but their responses also indicated that they were less affected by climate related impacts.

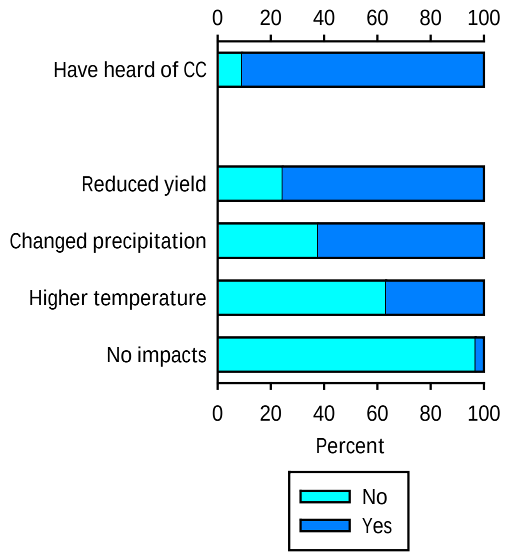

Figure 4.37: Indicated knowledge about climate change and expected impacts.

Figure 4.38 shows how respondents perceived current environmental problems. More than 75% of the respondents indicated that dust storms were 'serious' or 'very serious' problems. Drought, land degradation and desertification were also considered severe environmental problems. For these three categories confidence in own knowledge seemed to be high as 'don't know' was responded rarely. On the other hand, knowledge about plant diseases, rodent plagues and water availability seemed to be much less well developed and accordingly perception about the severity of these problems was considerably lower. Surprisingly, water availability was not considered a major problem, despite rapidly decreasing groundwater levels and increasing salinization of aquifers in some regions of Alxa and the perception of over 70% of interview respondents that water quality and quantity had declined (Dai et al., 2008).

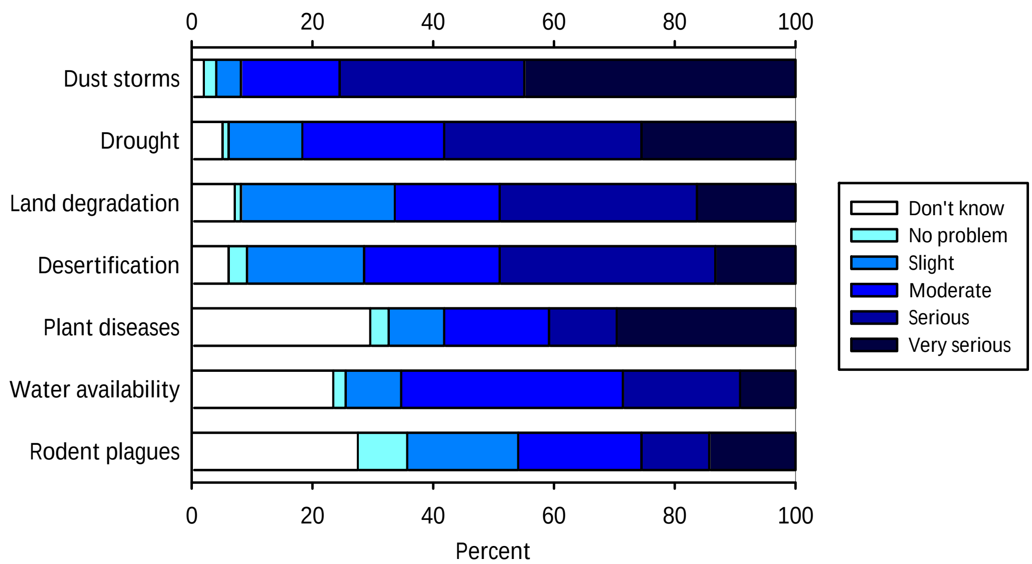

Figure 4.38: Perception of current environmental problems.

When asked how climate impacts had changed over the past 10 years, approximately 70% indicated that rainfall had decreased and 60% suggested that dust storms had increased in at least four out of ten years (Figure 5). Only a small minority indicated that there had been no changes. For stronger rainfall events, which could lead to flash floods and erosion, a large majority had not experienced any or only moderate changes, which are also likely to be within the margin of error.

Figure 4.39 clearly shows that there have not only been changes to climate related hazards, but that the population interviewed is also extremely exposed to them. Depending on the hazard between around 25% and 50% of respondents had experienced maximum income losses of 25% or more. It must be questioned how much of this loss was due to normal climate variability and how much was climate change induced, but the figures do point to the high exposure of Inner Mongolians to climate impacts.

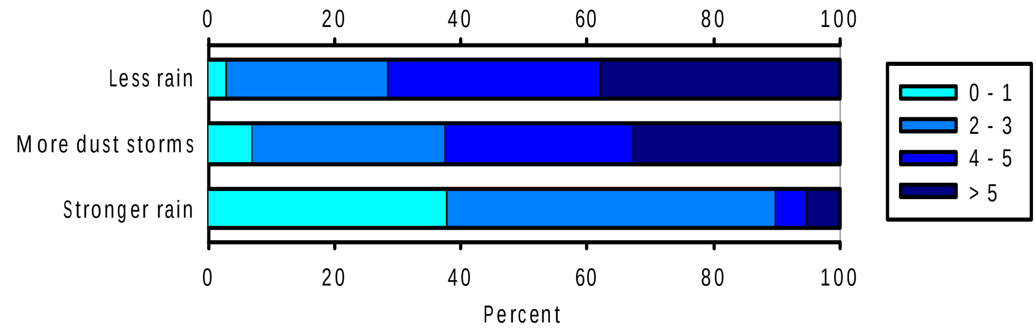

Figure 4.39: Perceived change of frequency of climate impacts during the past 10 years.

As indicated by the highly significant ($p < 0.001$) relationship between type of settlement and income loss due to drought and dust storms, the more isolated the settlements of the respondents were, the more exposed to the climate impacts they became. In order to cope with the losses, most respondents explained[26] they borrowed from the bank (60%). This was followed by spending less (57%), asking for government help (48%) and asking relatives/friends for help (30%). A minority of 10% indicated having left the region to cope.

Table 4.9 suggests that the impacts of extreme events on herders were rather evenly distributed, with particularly more severe losses at the high end of the spectrum. For farmers, losses were concentrated between 10% and 33%. This hints to a potentially greater resilience of herders against climate impacts as they have learned to adapt better to greater fluctuations of income.

[26] The average of the three hazards was used. Multiple responses were allowed

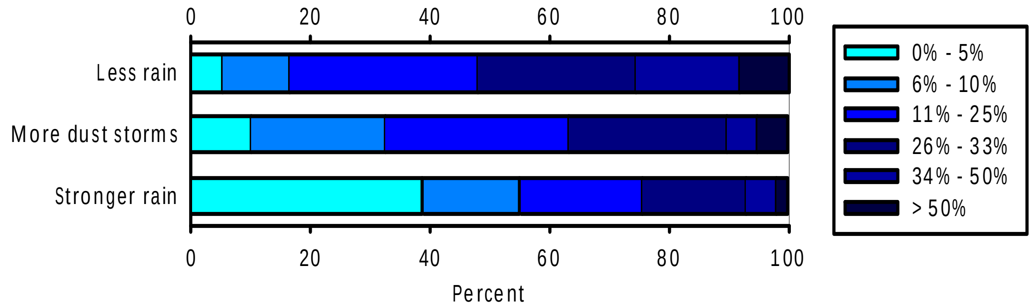

Figure 4.40: Maximum income loss due to climate related impacts during the past 10 years

Climate change related future temperature rise will likely enhance the stated trends. A large minority of 46% responded that they expected to lose income due to climate change and around one quarter expected to have to move. Given the normal high variability of income between years, additional climate change induced losses might exceed resilience. Compared to the 10% of respondents who coped with climate impact related income loss by moving, the expectation of one quarter having to move in the future due to climate change is a warning signal. Interestingly, farmers could potentially be more vulnerable to future climate impacts due to the higher concentration of income losses in a certain range (Table 4.9). But whether climate change will overstretch the limits of adaptive capacity will also depend on a number of other factors, including income development, market trends, environmental degradation and water availability, institutional settings and policies at the various levels.

Table 4.9: Different maximum income loss between farmers and herders due to climate related impacts

Income loss	Farmer	Herder
0-5%	0%	0%
6-10%	6%	15%
11-25%	39%	26%
26-33%	42%	15%
33-50%	11%	26%
>50%	0%	17%

4.7.3.3 Policy and management

Respondents were asked how useful they considered a set of environmental policies or measures (Figure 4.41). In order to test the results for robustness, the respondents were also asked to name the five policies on the list they considered the most important. This exercise showed a very similar order (economic diversification followed by green belts, windbreaks, artificial precipitation and water reservoirs) which verifies the results of the ranking procedure.

Economic diversification was considered the most useful environmental policy with over 60% acceptance while about 10% had no opinion. This is an interesting finding as it suggests that the respondents had a very clear understanding that more widespread economic opportunities offer a good way to reduce vulnerability to (climate) impacts by providing them with alternative income. This understanding is consistent with recent findings on raising adaptive capacity (e.g. McEvoy et al., 2008; Hinkel et al., 2010; Werners et al., 2010). Government response to address climate vulnerability could therefore be to invest in providing these opportunities, both directly through investment programs and indirectly through a broader education and provision of handicraft knowledge.

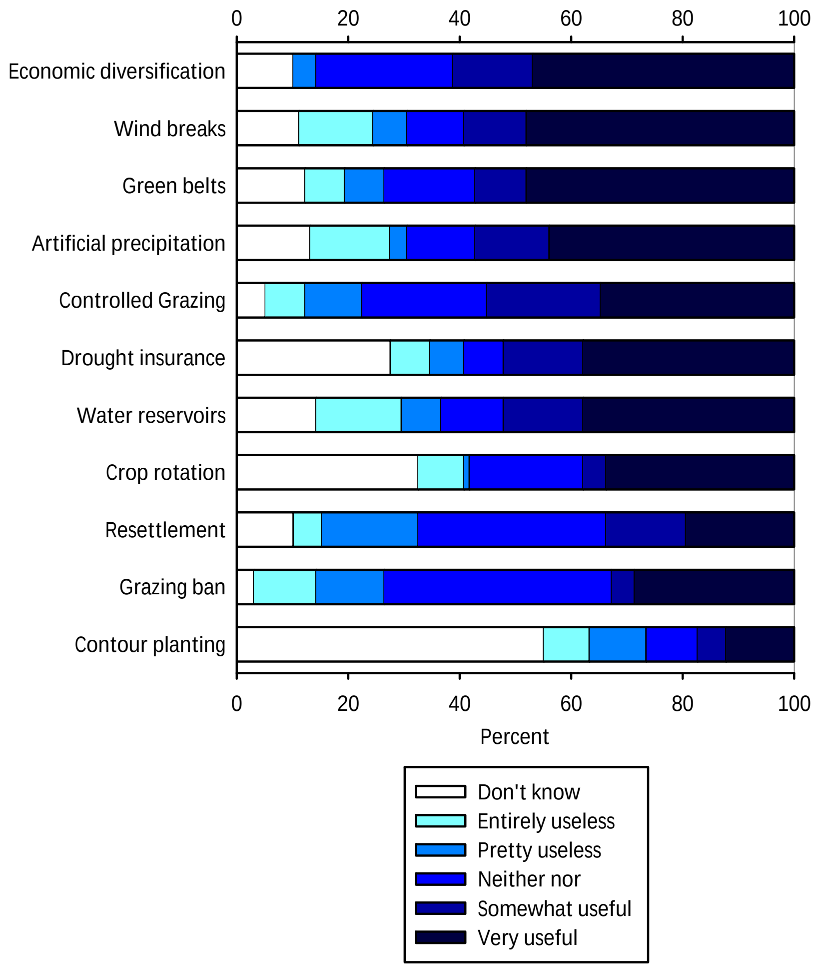

Figure 4.41: Perceived effectiveness of environmental policies and measures

Wind breaks and green belts are used to reduce denudation. Both measures were considered very useful with slightly under 60% approval. While increasing surface roughness with wind breaks can certainly be seen as a no-regret measure, green shelterbelts should also be evaluated in the light of tree water demand. When unadapted and less drought resistant tree species are planted in shelterbelts, groundwater levels have been observed to decrease (Dai et al., 2008).

Artificial precipitation was considered among the most effective policies by respondents and there were comparatively low levels of uncertainty. This is an interesting finding because research on the efficacy of artificial precipitation (or cloud seeding) is inconclusive (Wikipedia, 2009). China's cloud seeding program is the largest in the world, but claims that the technology increases precipitation by as much as 20% are difficult to verify because of the complexity of the processes and interference with other possible pollutants acting as drop or ice nuclei. The high confidence of the respondents therefore reflects trust in government proclamations.

Controlled grazing, the grazing ban and essentially also the eco-migration program are policies designed to reduce grazing pressure on the vulnerable rangelands. Since the introduction of the rangeland rehabilitation in 2001, about 20% of the rangeland has been closed throughout and another 30% has been put under seasonal or rotational grazing. In the areas under protection, there is evidence of vegetation recovery (Dai et al., 2008). Interestingly, the grazing ban was ranked much lower value than the controlled grazing. One reason for the low degree of acceptance of the grazing ban might be its negative side effects. For instance, Dai et al. (2008) reported that the absence of (some) grazing animals in the Helan Mountains led to accumulation of litter and subsequent increased wildfire risk. Additionally, the ban could have more negative effects on the income of the herders than controlled grazing.

Drought insurance was ranked sixth of all options. But when excluding the high number of indifferent responses, the measure ranked first place, suggesting that the concept of an insurance against climate hazards is not well understood. An insurance against drought (or other extreme weather events) takes a risk spreading approach to deal with climate hazards. For instance, Linneroth-Bayer and Mechler (2008) have shown how such a systems can be set up in developing countries. Next to a probabilistic approach to extreme event occurrence, climate-risk insurances require linking the public with the private domain because public backup is needed when damage costs are likely to surpass the capacities of reinsurance companies as a whole area is struck with a low-probability-high-impact event. When respondents were asked how much they were willing to pay to protect themselves against climate related risks, nearly two thirds indicated willingness to pay (WTP) between ¥ 6 and 50 per month. Whether this amount would be sufficient to set up an insurance is beyond the scope of this analysis. However, on average herders were willing to spend nearly twice as much on such an insurance as farmers (¥ 14.46/month vs. ¥ 7.31/month)[27]. Despite the fact that crops are more exposed to climate hazards such as drought and heavy rain than livestock, this finding is not surprising as most of the farming is irrigation based and does not strongly depend on rainfall. Reduction of water access, e.g. due to falling groundwater levels or increasing salinization of the aquifers due to unsustainably high irrigation levels would likely raise the WTP.

Table 4.10: Willingness to pay for insurance against climate related income loss.

0 – 5 ¥	29%
6 – 10 ¥	32%
11 – 50 ¥	33%
51 – 100 ¥	6%
> 100 ¥	1%

27 P < 0.001; the average WTP was determined by summarizing the weighted responses per amount class and then dividing by the number of respondents.

Water availability and quality are among the most severe environmental problems in Alxa and in some regions groundwater levels have fallen from 30m to 120m since the 1970s due to misuse and unadapted irrigation practices (Dai et al., 2008). Water management policies and measures, such as building water reservoirs or drip irrigation could potentially improve water availability and significantly reduce pressure on the water resources without affecting agricultural productivity (see Section 4.4 by Xu et al.). However, the responses indicate that water management was not among the highest priorities, just as water availability was not considered an important environmental problem next to dust storms, drought and land degradation (Figure 4.38).

Crop rotation and contour planting were among the lowest ranking measures, even when disregarding the high rates of indifferent responses, which suggest that these measures are not well known in the region. However, crop rotations can provide multiple benefits to land health and contour planting is known to strongly reduce soil erosion. While soil erosion due to heavy rains might be limited in Alxa (although deep gullies along the roads bore evidence of severe erosion in some areas), appropriate crop rotations could provide a means to increase agricultural productivity and sustainability.

Resettlement policy was also rated very low, with less than 40% of respondents believing in its effectiveness. Surprisingly, town and village dwellers were more positive of the policy (around 50%) than were respondents of the eco-migration settlements themselves (33%) and particularly respondents from isolated areas (4%). Disaggregation by occupation also showed that farmers believed in the effectiveness of the resettlement program much more than herders (53% vs. 15%). There are several possible answers to these apparently contradicting responses, but one interpretation might be that those who are directly affected by the policies also see the downsides better while those who are unaware of the benefits, such as isolated herders, fear the uncertainties of having to change their lifestyles. For instance, interviewees from two eco-migration settlements in Alxa agreed that living in their new environments provided them with important livelihood benefits, such as access to health services and transport (West, 2009). On the other hand living costs were reported to be higher with no income rise to balance it and a number of cultural differences, including language problems, complicated the transition (West, 2009).

The statistical analysis of the responses showed several significant effects by grouping variables. For all responses but water reservoirs, resettlement and contour planting, respondents living in isolated farms gave consistently lower responses on effectiveness[28] of the policies and measures. The same was true for respondents with only the lowest level of education, although not all post-hoc analyses were significant. This indicates that people living in more remote places and with low education levels tend to be less well informed about the effects of policies and measures. Finally, herders frequently responded with lower aggregate Likert scores than farmers, in particular to questions relating to agricultural lifestyles such as for green belts, crop rotation,

[28] Measured as the average value when assigning ranking numbers to the six categories. 0: 'don't know'; 1: 'entirely useless'; 2: 'pretty useless'; 3: 'neither nor'; 4: 'somewhat useful'; 5: 'very useful'

windbreaks and drought insurance. Herders also gave lower values to economic diversification, which indicates that in general farmers seem to be more open-minded to change, possibly because of their less isolated living conditions and greater proximity to other sectors of society.

When asked whether economic diversification was worth considering, 72% of all respondents answered with 'yes' and only 21% said 'no' (7% gave no answer). However, most also responded that they did not procure economic alternatives. The main reasons for not looking for alternative or additional opportunities were: a) lack of time; b) lack of money and skill; and c) lack of information. While lack of time is difficult to overcome, the other two responses could be addressed through appropriate training and funding programs. As with the question about the effectiveness of policies and measures, respondents living in isolated areas gave significantly less positive responses, confirming their lack of access to information and opportunities.

When asked what kind of information they would need to make better decisions, respondents valued forecasts on agricultural market developments and the weather most (Figure 4.42). Unsurprisingly, farmers valued information on agricultural markets and soil fertility significantly more than herders ($p < 0.001$) as this information is considered important for high yields and income. Agreement was lowest for information on water management. For farmers this can possibly be explained with their relative independence from precipitation, given that agriculture is entirely reliant on irrigation. But since there was no significant difference between the responses of farmers and herders it can be hypothesized that herders see little opportunity to manage water and consider it beyond control.

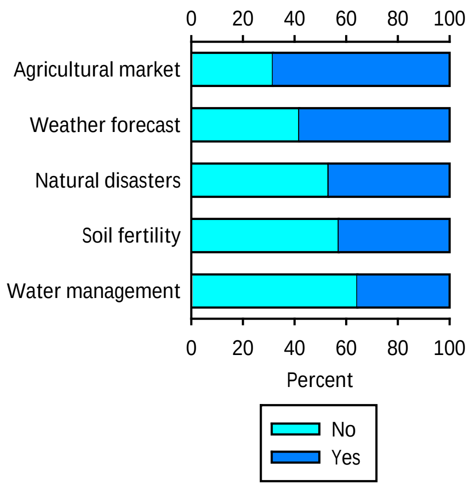

Figure 4.42: Information required for better decision-making

4.7.3.4 Living conditions: evaluation of the present, changes in the past and views of the future

A question referring to the present level of satisfaction showed that over 50% of respondents were either 'somewhat satisfied' or 'very satisfied', while one third indicated not being satisfied with current living conditions (Table 4.11). This perception is consistent when looking at the future (Table 4.12). A large majority expected improvements while only about 20% believed it would 'get worse' or 'stay the same'. One quarter of respondents had no opinion about the future.

Table 4.11: Evaluation of present level of satisfaction

Not satisfied	33%
Somewhat	45%
Very satisfied	12%
Don't know	10%

Table 4.12: Views of the future

Get worse	11%
Stay the same	8%
Get better	57%
Don't know	24%

When looking back in time, the number of those indicating that their living conditions had been worse off five to twenty years ago, rose continuously from just under 40% to over 50%, reflecting considerable development. On the other side the percentage of those who indicated that their situation had been better off in the past showed no clear trend and fluctuated between around 20% and 30%. These results are consistent with the generally optimistic view of the future and reflect considerable confidence that development policies will continue to benefit them.

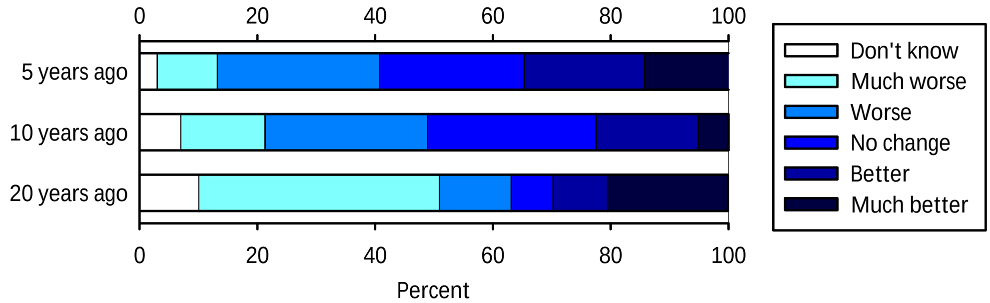

Figure 4.43: Perception of living condition changes over the past 5, 10 and 20 years

It is unlikely that climate change considerations play a role in expectations of the future as the majority is confident of the future whilst foreseeing negative climate impacts (Figure 4.37). A clear indicator for this is that eco-migrants gave significantly ($p < 0.01$) more positive views of the past than those living in isolated farms. An explanation might be that eco-migrants in Alxa reported livelihood improvements in the areas of access to transport, health services, and a wider range of goods and services, in their new settlements, compared to where they lived before (West, 2009).

4.7.4 Discussion

The results conclusively show the picture of a rural population that is already highly affected by current climate impacts. The income of farmers and herders is strongly exposed to climate hazards such as drought and dust storms and most have experienced considerable income losses due to these weather events.

Climate change is expected to increase those impacts and a large minority of respondents believes that moving away would be the only option to cope in the future despite being generally well adapted to the extreme climate variability and concomitant fluctuations of income. However, the majority currently believes to be able to cope with climate change through the existing safeguards such as loans and government support. Nevertheless, there seems to be some scope to invest in risk sharing mechanisms, such as insurances. But the willingness to pay for such services is highly dependent on the perceived vulnerability to climate impacts. It might therefore be useful to provide tailored services and target farmers and herders separately.

Along a similar line, there appear to be differences in the distribution of income losses that justify the conclusion that, whilst currently having lower income losses, farmers in the future might experience greater vulnerabilities to extreme weather events because their losses are more concentrated than those of herders whose income losses are evenly distributed over the entire range. If, as expected, climate change will result in more and possibly stronger droughts and dust storms, farmers will likely be hit harder. It remains to be seen how well farmers will adapt to greater impacts, but a promising strategy for reducing vulnerability is clearly to diversify economic activities. This strategy has been identified by all as the most effective measure and government policies should strive to provide opportunities, including training and funding programs.

The respondents also clearly identified several of the most important environmental problems, such as degradation and desertification, which are partly associated with climate change. On the other hand there is generally a low perception that water availability might become a problem in the future due to a continuing depletion of groundwater levels and increasing salinization of aquifers. This dichotomy of perceptions is consistent with existing environmental and development policies which tackle landscape degradation, for instance through grazing restriction, herder resettlement programs and forest shelterbelts. On the other hand, currently no policies exist that attempt to restrict irrigation agriculture, which has expanded considerably over the past decades and must be considered the main cause of declining groundwater levels. Future government policies should therefore attempt to increase the efficiency of agricultural irrigation practices and stop farmland expansion.

The general perception is that of improving livelihoods. Government policies have shown to be effective at delivering development over the last twenty years for a majority. Consequently, the trust in future development and growth is high. Climate change is not expected to seriously affect this trend. But there is a consistently lower positive response in marginal and isolated areas, which are mainly inhabited by herders. Government policies might therefore focus more on marginalized livelihoods and try to provide better services and information in remote areas.

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Annex: Survey Questionnaire (English version)

1. **Personal Information**

1.1 How old are you?

age	

1.2 Gender

male	female

1.3 How many members live in your household?

total number of household members	

of which children	

1.4 Where do you live?

town	village	isolated farm	eco-migration village

What is the name of your town/village?	
How many years do you live in the area?	

1.5 Education:

primary	secondary	high school	collage / university

1.6 Occupation

farmer	pastoralist	business/trade	government	other

if other: which?	

1.7a Income (monthly, unit: Yuan)

< 500	500-1000	1000-2000	2000-4000	4000-6000	6000-8000	> 8000

1.7b Expenses (monthly, unit: Yuan)

< 500	500-1000	1000-2000	2000-3000	3000-4000	4000-5000	> 5000

1.7c What are the major cost items (indicate percentage for each item)

housing			
electricity			
heating			
food			
living costs		which?	
production costs		which?	
education			

1.7d Household annual income (in Yuan)

2. Environmental problems and climate change

2.1a Have you heard of climate change?

yes	no

2.1b If yes, what does climate change mean to you (multiple answers possible)?

loss of property			
reduced yield			
higher temperature			
more/less rain			
no impacts			
other?		what?	

2.2 How do you evaluate current environmental problems?

(Indicate from 1 "no problem" to 5 "very serious"; 0 is "don't know")

	no	slight	moderate	serious	very	don't

	problem				serious	know
land degradation	1	2	3	4	5	0
desertification	1	2	3	4	5	0
drought	1	2	3	4	5	0
dust storms	1	2	3	4	5	0
water availability	1	2	3	4	5	0
plant diseases / insects	1	2	3	4	5	0
rodent plagues	1	2	3	4	5	0

2.3 How do you evaluate past environmental problems?

2.3a Rainfall / drought

2.3a.1 In the past 10 years how often has there been notably less rain than usual?

0-1	2-3	4-5	>5

2.3a.2 What kind of impacts?
(For each option use plus (+) for more; minus (-) for less; 0 for no change)

agricultural yield			
livestock based products			
other products (e.g. honey)		which?	
water availability			
erosion			
plant diseases / insect attack			
rodents			
income			
other?		which?	

2.3a.3 How much income loss (only indicate the highest range you have experienced)?

0-5%	5-10%	10-25%	25-33%	33-50%	> 50%

2.3a.4 How did you cope with the loss (name up to three)?

ask government for help			
get loan from bank			
ask relatives for help			
spend less			
leave region			
other?		which?	

2.3b Extreme rain events

2.3b.1 In the past 10 years how often has there been notably stronger rain than usual?

0-1	2-3	4-5	>5

2.3b.2 What kind of impacts?
(For each option use plus (+) for more; minus (-) for less; 0 for no change)

agricultural yield	

livestock based products			
other products (e.g. honey)		which?	
water availability			
erosion			
plant diseases / insect attack			
rodents			
income			
other?		which?	

2.3b.3 How much income loss (only indicate the highest rate you have experienced)?

0-5%	5-10%	10-25%	25-33%	33-50%	> 50%

2.3b.4 How did you cope with the loss?

ask government for help			
get loan from bank			
ask relatives for help			
spend less			
leave region			
other?		which?	

2.3c Sandstorms

2.3c.1 In the past 10 years how often have there been notably more sandstorms than usual?

0-1	2-3	4-5	>5

2.3c.2 What kind of impacts?
(For each option use plus (+) for more; minus (-) for less; 0 for no change)

agricultural yield			
livestock based products			
other products (e.g. honey)		which?	
water availability			
erosion			
plant diseases / insect attack			
rodents			
income			
other?		which?	

2.3c.3 How much income loss?

0-5%	5-10%	10-25%	25-33%	33-50%	> 50%

2.3c.4 How did you cope with the loss (only indicate the highest rate you have experienced)?

ask government for help			
get loan from bank			
ask relatives for help			
spend less			
leave region			
other?		which?	

2.4 Attitude toward rate of change of climate related and environmental problems
(Indicate perceived changes from strong decrease (--) to strong increase (++); tick 0 if you don't know)

	strong decrease	decrease	no change	increase	strong increase	don't know
temperature change	--	-	+/-	+	++	0
precipitation change	--	-	+/-	+	++	0
drought length	--	-	+/-	+	++	0
number of dust storms	--	-	+/-	+	++	0
water availability	--	-	+/-	+	++	0
land degradation / desertification	--	-	+/-	+	++	0
flash floods	--	-	+/-	+	++	0
salinization	--	-	+/-	+	++	0
rodent plagues	--	-	+/-	+	++	0
plant diseases / insects	--	-	+/-	+	++	0
invasive species	--	-	+/-	+	++	0

2.5 What are the drivers of the change?
(Please rate which drivers you consider important from 1 "no influence" to 5 "very important" for each possible driver; tick 0 if you don't know)

	population growth	industrialization	overgrazing	grazing ban	(irrigation) agriculture	cultivation on grassland	woodland green belts	deforestation	climate change	any other? which?
temperature change										
precipitation change										
drought length										
number of dust storms										
water availability										
land degradation / desertification										
flash floods / heavy rains										
salinization										
rodent plagues										
plant diseases / insects										
invasive species										

3. Policy and management

3.1 How do the environmental and land use policies stated below affect you (Indicate from 1 "no effect" to 5 "very strong effect"; 0 is "don't know")

Policy	impact	describe how the policy affects you
Grazing ban act		

Land lease reform		
Urbanization and new countryside project		
Forest property right act		
Other? Which?		

3.2 How does the government help you in a crisis (name up to three options)?

government emergency fund			
insurance			
infrastructure			
tax return			
provide information			
other?		which?	

3.3 In your opinion, what should be done to improve your living condition (name up to three options)?

provide more funds			
improve infrastructure			
expand insurance coverage			
provide better information			
other?		which?	

3.4 Could you obtain a (bank) loan if you wanted one?

yes	no

3.5a How useful do you consider the following environmental policies or management practices? (Indicate from 1 "entirely useless" to 5 "very useful"; 0 is "don't know")

		entirely useless		neither nor		very useful	don't know
1	grazing ban	1	2	3	4	5	0
2	ecological emigration	1	2	3	4	5	0
3	green belts of trees	1	2	3	4	5	0
4	crop rotation	1	2	3	4	5	0
5	enclosed grassland	1	2	3	4	5	0
6	grazing rotation / controlled grazing	1	2	3	4	5	0
7	wind breaks	1	2	3	4	5	0
8	artificial precipitation	1	2	3	4	5	0
9	contour planting	1	2	3	4	5	0
10	drought based insurance	1	2	3	4	5	0
11	water reservoirs / wells	1	2	3	4	5	0
12	reforestation / afforestation	1	2	3	4	5	0
13	reduction of stocking rates	1	2	3	4	5	0

14	support for economic diversification	1	2	3	4	5	0
15	Alternative livelihood / different work	1	2	3	4	5	0

3.5b Of the policies above rank the five policies you consider the most important

Policy (number)	Rank
	1
	2
	3
	4
	5

3.6 How much would you be willing to pay for an insurance that protects you against climate related income loss (in Yuan per month)?

< 5	5-10	10-50	50-100	> 100

3.7 Would economic diversification (e.g. additionally producing honey or selling herbs) be an interesting additional income?

yes		why don't you do it?	
no		why not?	
What kind of economic diversification would make sense to you?			

3.8 What kind of information would you require to make better decisions (name up to three options)?

weather forecast			
agricultural market			
soil fertility			
water management			
natural disasters			
other?		which?	

4. Livelihoods

4.1 How satisfied are you with your present living conditions?

very satisfied	somewhat satisfied	not satisfied	no idea

4.2 How have your living conditions changed over the past 5, 10, 20 years? (Give values from 1 for "much worse" to 5 "much better"; indicate 0 for "don't know")

	much worse		no change		much better	don't know
past 5 years	1	2	3	4	5	0
past 10 years	1	2	3	4	5	0

past 20 years	1	2	3	4	5	0
Explain what has caused the changes?						

4.3 What is the view of the future of your livelihood / general well-being?

get better	stay the same	get worse	no idea
Why do you think that?			

4.4 How would your life change if the climate became hotter, drier, less predictable?

get better	
no change	
get poorer	
would have to move	
don't know	

4.5 If you had ¥10,000 extra money, what would you do with them (name up to three options)?

invest in agriculture			
improve housing			
invest in livestock			
invest in water management			
leave the region / move to town			
entertainment / go on vacation			
other?		which?	

4.8 Opportunities for climate governance

Some lessons learnt from the Alxa-Inner Mongolia case study with particular attention to the role of ecological science.

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4.8.1 Introduction.

Complex problems cannot be solved by simple solutions. The same applies with regard to institutions and organisations. As environmental problems increase in intensity, variety and scale, the interactions between their different side effects multiply and accelerate. With every interaction, a new social-ecological situation emerges thus making largely obsolete the organisations and individual practices, which were developed to tackle the previous problems. This is one of the reasons why the concept of adaptive governance is now so widespread: because in times of accelerated environmental change, rules, arrangements, and capacities need to be constantly updated and revised. We all need to learn not only from past mistakes but also what are the new conditions and challenges we now face.

China is currently in a unique position to integrate its environmental science and policy in a manner and decisiveness, which probably cannot be integrated anywhere else in the World. Such challenge, however, is not devoid of risks. In the following lines, and by drawing from the lessons learnt during our collaboration with Chinese colleagues during the case study in Inner Mongolia and the Alxa region in particular, I intend to provide a very preliminary assessment of the potential to transform the existing climate risks in Northern China into opportunities compatible with the general goal of sustainable development. This task is carried out by using the general concept of *Integrated Climate Governance* as an analytical and heuristic devise (ICG; Tàbara, 2009). In what follows, I explicitly refrain from reproducing the arguments already stated in that reference and focus on the key role that science, and in particular the science of Ecology, as well as in the role of communication, learning and public engagement is and may play in this respect.

4.8.2 Introducing social-ecological systems thinking in Integrated Climate Governance.

The concept of Integrated Climate Governance has been defined as:

> "the structured generation and use of tools and methods that combine a plurality of legitimate but divergent interests and sources of knowledge and judgement for: (i) the comprehensive assessment of climate risks, (ii) the design and implementation of policy instruments, and (iii) the creation of communication, engagement and transformative learning capacities, all aimed at producing long-term efficient, equitable and socially and ecologically robust climate strategies. ICG deals both with adaptation and mitigation, as well as development risks and opportunities, and does so from a multi-scale, multi-level, multi-domain and transition-oriented perspective" (Tàbara, 2009).

Graphically this approach can be expressed as:

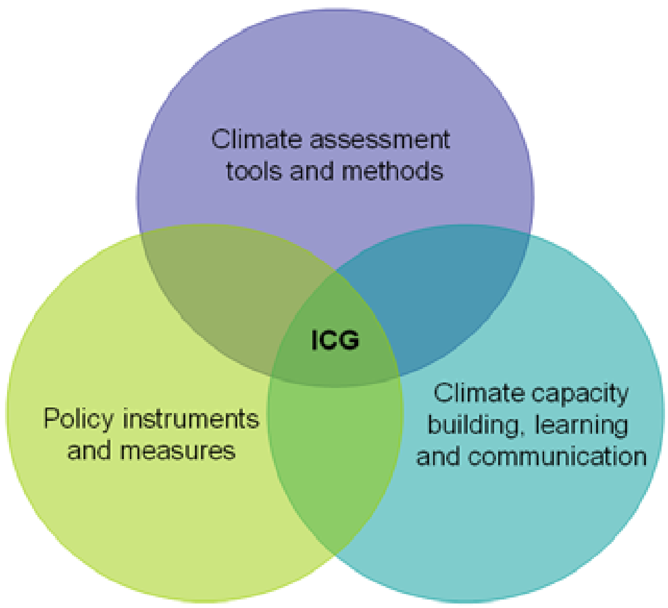

Figure 4.44: Integrated Climate Governance.

Elsewhere (Tàbara, 2009) I have argued that fulfilling the functions and processes entailed in ICG may be one of the most robust ways to address the current global challenge of climate change and to meet the requirements of sustainable development. A central assumption of ICG regards the contention that the development of climate assessment tools, of policy instruments and measures, and of agent and institutional capacities to deal with it, is best carried out whenever interaction between these three domains occurs. In fact, the main source of climate learning must be found, not so much in the processes which occur within each domain but from the interaction between each of them.

For the case of China, and in particular for the Inner Mongolia and Alxa case study, a reflection on the specific role of the science of ecology -and in particular, of restoration ecology- is now playing climate change adaptation policy is specially important. However, while there is already a decisive move in China to introduce new ecological concepts in the existing official policy, it is also the case that such move in some cases may be arriving too late as to redirect current economic growth. For this reason, it is not only 'science in general' which is and will be crucial in trying to make any possibility for an Integrated Climate Governance in a reality within the Chinese context, but most importantly, the *type of scientific perspective and the processes* employed to make such scientific knowledge useful for policy which needs to critically examined in this respect.

One of the pioneering thinkers using ecological knowledge as to offer guidance for social transformation was Barry Commoner (1971). His simple but very powerful analysis contained in his *The Closing Circle* (1971) provided the basic 'Four Laws of Ecology' which seem particular well suited to help understanding and redirect the current situation of environmental change which now faces the Chinese society[29]. According to his view, in ecological systems:

a. *Everything is Connected to Everything Else.* There is one ecosphere for all living organisms and what affects one, affects all.
b. *Everything Must Go Somewhere.* There is no 'waste' in nature and there is no 'away' to which things can be thrown.
c. *Nature Knows Best.* Humankind has fashioned technology to improve upon nature, but such change in a natural system is likely to be detrimental to that system.
d. *There Is No Such Thing as a Free Lunch.* Everything comes from something. There's no such thing as spontaneous existence.

Learning such lessons may take some time. Learning may be somewhat delayed too, but in the current conditions of economic globalisation and global environmental change time is running very fast. Learning can be carried out in an anticipatory, reflexive way or in a simple 'trial and

[29] I also use this reference given the particular well suited analogy of the circular thinking both within the Chinese tradition and within our ADAM policy appraisal and research journey.

error' mode (Tabara, 2002). Nevertheless, when risks get to such scale and intensity as to undermine the actual basis for development and life, such errors are no longer possible. Within our research context in Inner Mongolia and the Alxa regions, Laws 2 and 4 appear especially important. For this reason, a brief exploration of the meaning of ecological systems' thinking and its potential role in environmental policy may be particular important within the framework of Integrated Climate Change.

Ecological systems, being these considered as coastal systems, steppes, river basins, marshlands or mountainous areas, all perform multiple, unique and diverse functions. The adequate performance of each of these functions depends to a large extent to the adequate performance of the other ones. While there is never a situation of total equilibrium in dynamic ecosystems (as the saying tells 'a fish in equilibrium is a dead fish') it is possible to avoid system's collapse, and enhance the production of their multiple services by avoiding certain non-return thresholds of exploitation and by combining, among other things, certain controlled shocks and perturbations with processes of regeneration and renewal. Reducing the performance of an ecosystem to one single function –such as annual biomass production for human consumption- tends to undermine many other functions which are related to the preservation of its health in the long term –such as the need to restore the conditions which made life possible in the first place. A key lesson from ecology is that the exploitation of an ecosystem is not simply possible without its conservation and that the transformation which such exploitation entailed needs to be combined with new periods and measures for renewal and reorganisation[30].

In this lines, a quite elaborated but still quite dualistic interpretation of these ecological insights has been produced by C. S. Holling (2001) and colleagues with the notion of *adaptive cycles* -and when connected in hierarchical mode, a 'Panarchy' of ecosystems. Such notion is represented in Figure 4.45.

[30] In another context (Tabara, 2005), I have argued that the most optimal way to obtain services from an social-ecological system is by allowing for maximum hybrid self-reorganisation of both types of system, in a way that can enhance both social and ecological functions of both and sustainability learning depend on the capacity to learn precisely this.

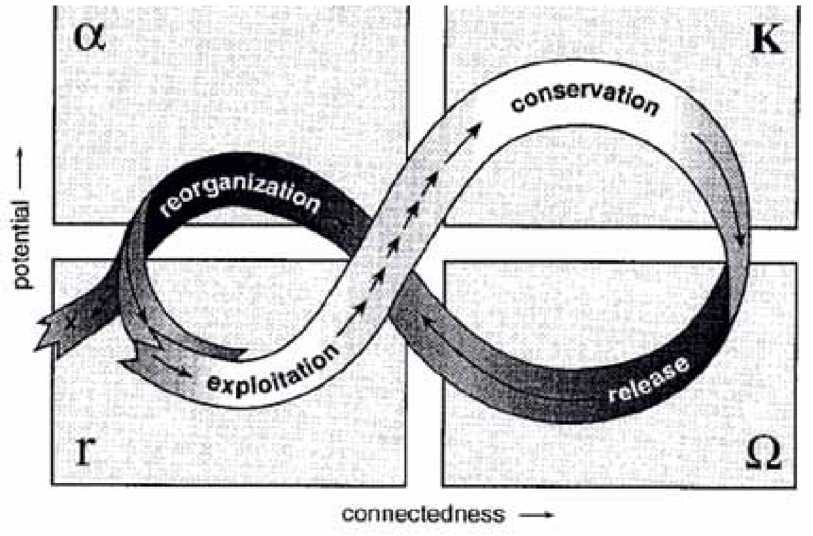

Figure 4.45: The adaptive cycle.

All these developments in the science of ecology and now in social-ecological thinking (Berkes et al. 2003) are now helping to reframe the way we approach and conceptualise our human interaction with the natural world. This is of paramount importance within the Chinese context, precisely because its openness to integrate science into policy and doing so in the big way. Some concepts such as 'carrying capacity' which are still used to do so, tend to be associated with the maximization of an unique function of the ecosystem. Nevertheless, now it seems to be the time which and need to be replaced by other more nuanced concepts and theories which are based on the acknowledgement of different time cycles, limits, and diverse functions and services which ecosystems, and more broadly social-ecological systems, perform. China is already engaged in doing so, as has been illustrated in the Alxa region with the plans to restore steppes and bring back to life a dried lake (CAS 2009a, 2009b). But how long such achievements will last and will be integrated in a more coherent strategy that will integrate the new climate change risks, concerns and opportunities is still open to debate. In the next section I move to specify some possible guidelines which could help moving in that direction, assuming that the general tenets of Integrated Climate Governance are seen as a valuable approach to meet both climate and sustainable development goals.

4.8.3 Opportunities for ICG in China

What follows is only a preliminary assessment of a possible set of guidelines for action to make ICG more relevant within the Chinese context and specially, regarding our case study area of Inner Mongolia and the Alxa regions. Given that ecological restoration policies are of critical importance in the Chinese context, the following normative statements should also be read along these lines. In particular, in order to develop and implement strategies which follow a more Integrated Climate Governance approach scientist and policy makers may benefit if they:

- Favour, apply and use systemic concepts to understand exiting problems and provide guidance for policy making. Such as those of 'river basin management'

- Attempt to develop tools and methods for assessment which deal with multiple constraints and non-linearities, including critical relationships between different resource use (water, energy) and its effects of particular vulnerable facilities, such as electricity or sanitation.
- Develop and implement an anticipatory approach. Learn to anticipate 'expected surprises', regarding the misuse of natural resources and over-generation of pollution flows.
- Experiment and learn at local level and by making multiple experiments in different conditions *before* taking large decisions affecting all levels of governance and social-ecological conditions. Learn to understand and apply precaution in a broad sense. Learn from the past mistakes and openly search the truth (e.g., separate sense than non-sense by asking why as a methodological process to search for the root of social-ecological change).
- Combine different learning experiences of restoration of ecological systems to support larger strategies of climate policy which are able to combine both mitigation and adaptation goals. Consider thinking in terms of social-ecological resilience and adaptive cycles.
- Work within self-imposed limits and thresholds before natural conditions impose their ones. Combine sufficiency (limits) criteria with ecoeficiency. Only working with efficiency is likely to create new rebound effect and do not trigger the necessary transformations both in institution and individual practices.
- Think in terms of diversity –of conditions, solutions, processes, agents and institutions-rather that in terms of uniformity. Complex social-ecological conditions, problems and risks demand the management and stimulus of complex forms of organisation and interaction.
- Promote incentives for action, before sanctions and punishments.
- Put a great deal of efforts, whenever possible, in developing new processes of multiple-directional communication, agent transformation and engagement.

Ecological restoration science and policy is likely to play a tremendous role in China in the coming years, and this is not independent to what can and should happen with climate policy. Restoration is possible and necessary by optimising the uses of critical resources such as water but also others such as land and energy. An increase of agricultural productivity, combined with other measures of soil conservation and reduction of pollution sources –including those from industry- should increase the potential for regeneration of ecological systems. In this regard, within the ADAM regional case studies it has been argued that one of the best ways of doing so is by the mainstreaming of climate concerns both in water and land use planning.

4.8.4 Conclusion

It is likely that one of the greatest challenges now facing China within the domains of environmental science and policy and sustainable development lays now in the restoration of many its highly overexploited ecosystems. Climate change perhaps offers one of the best opportunities to readdress such situation by increasing the optimal use of many ecosystems now being exploited in a highly inefficient way. Increasing the efficiency in the use of the water, land, and life ecosystems, e.g. by allowing to perform their multiple functions and yield their multiple services, by combining conservation and exploitation and different stages of the ecosystem's dynamics - should release the necessary pressure to as to allow for their progressive restoration and regeneration, thus increasing the total social-ecological output in the mid term.

It appears that in China, and in particular in the Inner Mongolia and Alxa regions, ecological science is now playing an increasing role in supporting policy decisions regarding the use of natural resources and land use planning. However, to use one single scientific approach to inform policy, in a similar way that economics have done so far dominated such interaction is also risky (as demonstrated with the global financial crisis). In this paper I have argued that it is not only important to get the right scientific ecological insights to support policy making, but most critically, to develop the most adequate *processes* which make sure the integration of plural sources of knowledge and different but legitimate interests at stake. Indeed, one of the most important barriers for adaptation identified in our case study region regards to the processes of knowledge sharing and horizontal dialogue. Overcoming the existing difficulties which different institutes, researchers and local agents encounter in transferring knowledge and in becoming part of the processes of climate knowledge production, transformation, and implementation may be one of the key policy actions that need to be addressed in this domain.

The re-emergence of the disappeared Yunan lake or the restoration of large tracks of very degraded steppes in the Alxa League as a result of a decisive policy action is an very illustrative example of the possibilities that such more holistic and systemic approach to bring back to life ecological systems which were very much degraded can and is already being carried out in China. It may be also the case that it is precisely in China where the implementation of such new ecological thinking concepts can be implemented in a most significant way than anywhere else in the World. However, in order to make it possible for such policies and measures to last in the long run, and to be compatible with the imperatives of sustainable development in the context of global warming, still a lot more work needs to be done within the third pillar of ICG: that which concerns the communication, learning and engagement of agents at all levels of policy and social action. This should facilitate the public understanding of the type of risks we all now face and to create countless numbers of opportunities in the many contexts of action in which climate and sustainable development can and needs to be combined.

To conclude, the Circle may be closing in China, but not more or less than is happening in other parts of the total World in which we now live in. This is why, more than ever before, a huge cultural reframing process is required with regard to how we see the challenges that each nation and individual now face in this unprecedented situation of environmental change. As new large scale risks emerge and new interactions between persistent problems multiply its negative effects, a new way of defining both the ends and the means of science and policy is needed: that which moves current major institutional and individual efforts on economic growth to sustainable development and from global competition to global cooperation and coordination.

4.8.5 References

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4.9 Integrated policy appraisal on adaptation and challenges

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The various strategies in Alxa climate change adaptation and mitigation have been appraised under the guide of Policy-option Appraisal Frame (PAF) (Haxeltine, et al., 2007) developed by ADAM Project. The PAF has three pillars, i.e. analysis, participatory and modelling with for stages, i.e. scoping stage, visioning stage, experiment stage and evaluation stage. We have completed all four appraisal stages with the three pillars during the past three year's study. In this sub-section we will firstly make remarks on various climate change impacts on agriculture, water resources and land use, and then list corresponding adaptation measures or policies with appraisals basing on questionnaire, in-depth interview, stakeholder workshop, literature review and modelling results. Finally we present adaptation challenges and recommendations as a conclusion.

4.9.1 Remarks on climate impacts on agriculture

Climate change with increasing extreme events has brought various direct and indirect impacts on natural environment and human society. The warming is one of the most important characteristics in Alxa climate change over past 50 years. The season shifts with warming has the distribution of agricultural hazards changed during seasonal cycle, and corresponding impacts are gradually emerged in many aspects of crop plantation. The impacts on agriculture are logically described by a flow-chat (Figure 4.46). This flow-chat demonstrates logical connections and relationships among various impacts on agriculture resulting from climate change. The key impact of the warming climate is to have soil moisture decreased and enhance the water shortage crisis in such extreme arid area. The warming climate had made about fifteen consecutive warm winters in China since 1987. The warm winter is of a function in protecting farmland pests from frozen, and it increased the past number in next spring and summer afterwards. So, the pest hazard becomes more and more serious in Alxa region. Moreover, it has been found that some species of pests has moved onto Alxa from other places with global warming. Broad pest and mouse hazards appeared in 2009 spring in west Inner Mongolia owing to warm winter. As reported by meteorological daily on 15th and 19th May 2009, seriously pest-hazard grasslands are found in Damao Banner of Baotou city, Wulatezhong Banner of Bayannaor city and Dengkou county, which hazard areas are two million, 1.8 million *mu* and 0.6 million *mu*, respectively. And mouse hazard also jointly appears in the three areas, in which the maximum mouse hole density accounts for 1500/ha. There are 8.9 million mu of steppe are seriously damaged by mice in Azou Banner of Alxa League in 2009 spring (http://www.cnr.cn/nmgfw/xwzx/jjnmg/200903/t20090326_505283729.html).

These hazards are very likely one of the consequences resulting from warming in winter and spring seasons. Another warming effect is to advance first spring day and therefore first sandstorm event. For instance, the first sandstorm event appearance in 2009 is 20 days earlier than its climate mean. The warming spring also made local crop seeding season advanced, and crops seedlings are more easily damaged by frozen and sandstorm. As a result the warming has substantially enhanced the risks of local agriculture, and a lot of young farmers thus left their villages to find alternative livelihood outside, which led to farmland abandonment and land degradation.

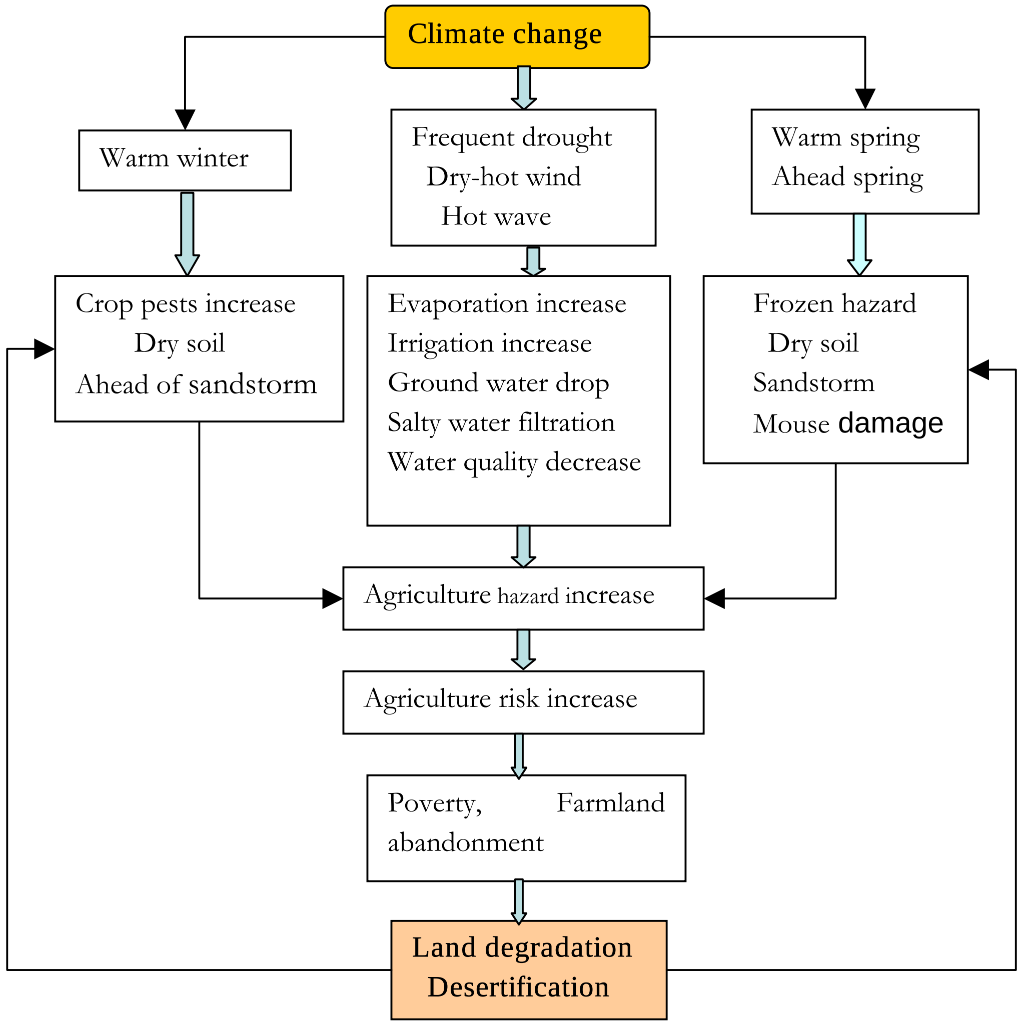

Figure 4.46: Flow-chat of climate change impacts on agriculture in Alxa League

4.9.2 Impacts on land use and water resources

The widely concern is the climate change impacts on land use, ecosystem and water resources in Alxa League due to sandstorm and Heihe River reallocation implementation. The impacts and their relationships are simply depicted by a flow-chat (Figure 4.47). Surface evaporation increase and water scarcity are major climate warming impacts on local ecological system and land use. The water shortage has led to over-exploiting ground water in oases and farmland area, in addition to increased population pressure due to ecological migration, which results in drop of ground water table at oases around and salty water filtration to deep aquifers. So the water quality is declining and can not be drunk by local habitants in many places. This directly brought on oases shrunk with marginal land and steppe degradation. On the other hand, evaporation increase made runoff decrease especially in lower reaches of Heihe River and the rivulets in Helan Mountain, especially. For example, the water had not flowed into East Juyan Lake during 2000-2003 although the water discharges were conducted in Hehe River mid-reach owing to evaporation and leakage in open river channels of the lower reaches. On the other hand observations confirm that many rivulets in Helan Mountain have dried up in the past decades with climate warming, leading to grassland degradation and general negative balance of ground water in Azou Banner of Alxa League. The ground water drop has become a major crisis in local economic growth and environmental restoration against land and vegetation degradation although gazing ban has been implemented in the area.

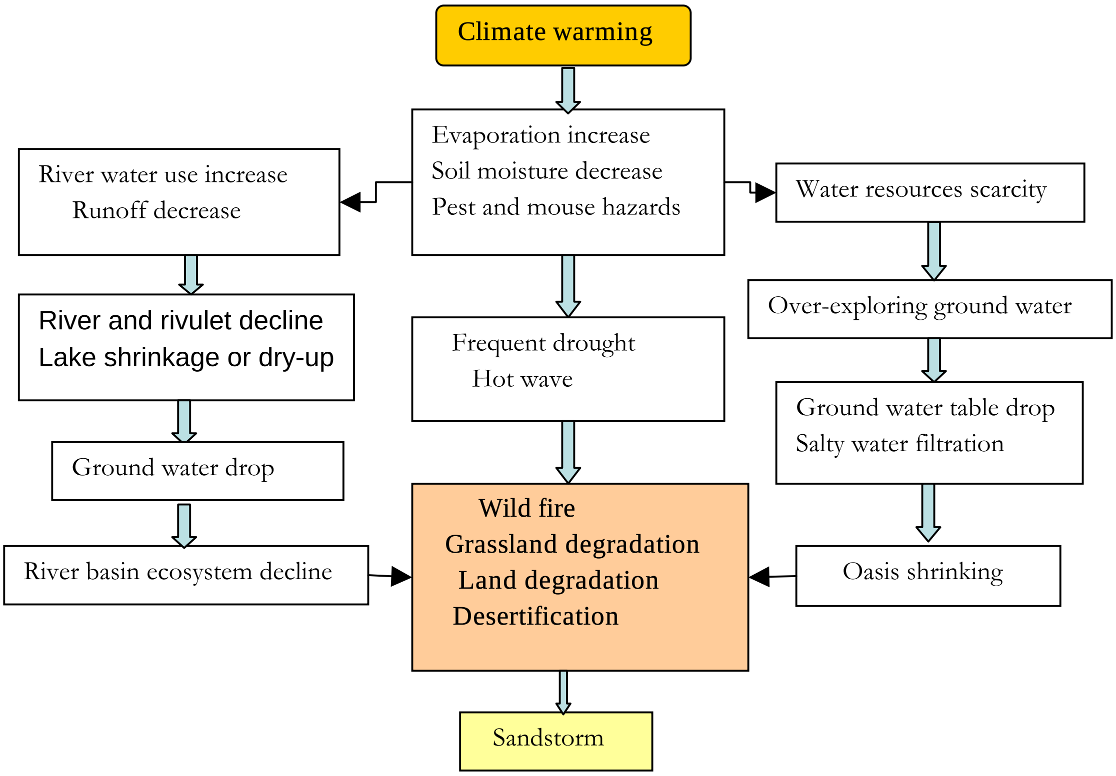

Figure 4.47: Flow-chat of climate change impacts on land use, water resource and ecosystem in Alxa League.

4.9.3 Anthropogenic impacts

Anthropogenic influence has become one of key drivers to environmental degradation with increasing population that demands more and more natural resources in addition to climate change impacts. Improper human activities have caused a lot of problems in land use, water resources and agriculture. They are partly listed as following:

- Illegal reclamation
- Over-exploiting ground water
- Over-breading animals or overgrazing
- Stocking goat
- Urbanization
- Extraction of traditional medical plants
- Extraction of Nostoc flagelliforme
- Cut trees or shrubs as household fuel
- Over-taking river water
- Planting improper trees or woodlands

Nostoc flagelliforme (*NostoCCommunevar.flag-elliforme（Berk.exCurtis）Born.exFlah*) is a kind of *Nostocaceae* and lives in arid or semi-arid zone with annual precipitation 50-250mm (Zhang et al., 2008). It is regarded as an extreme valuable plant for cooking food. There were about ten thousand of persons who entered Alxa every year from adjacent Ningxia Hui autonomous region for extracting Nostoc flagelliforme and other medical plants. This extensive exploitation has caused severe damage to local grassland. The improper human activities all brought negative contributions to environment in the region. Hence, how to regulate and control the improper human activities has become one of urgent tasks for policy makers at different levels except for climate change adaptation and mitigation.

4.9.4 Appraisal of Adaptation strategies

There are series of adaptation policies and measures issued in cope with climate change, land degradation and water scarcity in Alxa League in the past decades. They can be divided up into several groups according to different sectors or strategies.

Grazing strategy:

- Grazing ban
- Rotational grazing
- Limited grazing
- Seasonal grazing
- Goat-grazing ban
- Enclosure or fencing
- (Partly) stall-fed animals

Migration strategy:

- Construction emigrant village
- Transfer to farmers
- Transfer to workers in mineral or other industries
- Leave homeland to find alternative livelihoods outside

Water-saving strategy:

- Improving water transfer channels
- Water facility construction
- Green house construction
- Plastic film mulching in cropland
- Plastic film house
- Pipeline irrigation system
- Forbid water-consumed crop plantation
- Forbid or control water-consumed industry
- Cyclic water use in human society
- Make adaptive water price
- Government-controlled water-taken permission

- Heihe River reallocation project
- Yellow River water Introducing plan

Other strategies:

- Aerial seeding
- Artificial rainwater
- Grassland and forest rehabilitations
- Grain for green or Farmland conversion
- Conservation zone construction
- Shelterbelt woodland construction
- Control population and forbid outside immigrants

where the Yellow River water Introducing plan refers not only the four-ladder pumping water project from Yellow River to Luanjingtan, but also a projected plan (The Eleventh Five-year Plan for economic and social developments of Alxa League, 2006) for introducing Yellow River water to Bayanhot, capital city of Alxa League to meets increasing demand of water use and control over-extraction of ground water.

The implementation of the adaptation policies has achieved positive goals on environmental restoration, i.e., the large-scale land degradation is successfully controlled, and some of local eco-states are significantly ameliorated in Alxa League. Nevertheless, a number of problems gradually emerged since the adaptation policies lunched, for instance oasis decline, ground water drop, water quality decrease, policy sustainability, policy collocation at different levels, etc (Dai et al, 2008). This implies that the policies should be improved and developed with social development. Hence it is necessary to make systematic assessment to those from various aspects and directions. A series of appraisal activities were conducted in Inner Mongolia and China in the past three years, such as field survey, questionnaires, in-depth interview and stakeholder workshop. Qualitative and quantitative results are obtained from these assessments through analysis and modeling. Assessments for several key policies on climate adaptation are presented in following content.

The final assessment is derived from the 2006 survey. 84% of the 132 respondents confirms the positive effects of the policies against land degradation and water resource scarcity in Alxa League (Figure 4.48).

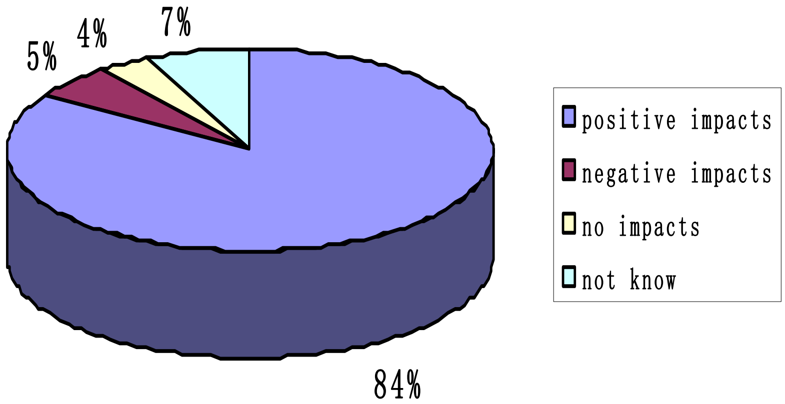

Figure 4.48: Questionnaire statistics from 132 respondents in 2006 survey was conducted in Alxa survey on climate change impacts and policy effects in combating land and degradation.

A further investigation shows that the effects of the adaptation policies concentrate on vegetation cover increase, sandy land shrinkage, sandstorm decrease, etc according to 2006 survey in Inner Mongolia. This is qualitatively consistent to remote sensing results (Guo et al, 2004, Duo et al, 2008).

Grazing strategies are major adaptation measures against land degradation in Alxa League. A numerical experiment on stocking is conducted with FORSPACE model (Kramer et al, 2001, 2003) under current climate forcing. The model is employed in simulating interactions among surface vegetation, wild fire and animal grazing in west piedmont of Helan Mountain. A preliminary result shows that total sheep and goat would be died if no additional herds compensation in dry seasons due to very low net ecological productivity (NEP) in the steppe. Hence, herds base construction and to make proper gazing strategies are important in stocking animals. Seasonal grazing, rotational grazing and grazing ban have been implemented in Alxa League for the past decade, and its positive effects are confirmed by local stakeholders. The questionnaire statistics on grazing-ban demonstrates 49% or 25% election rates of 132 respondents who choose 'distinct' and 'very distinct' for its effect, respectively (Figure 4.48). But some of the respondents interviewed in depth argued about total grazing-ban and indicated that proper grazing is favorable to some sorts of shrub growth, while some others are worried about the accumulation of dry biomass or liter of vegetations because they could not be decomposed quickly in such arid climate zone. In fact, excess accumulation of liter become a resistant factor against local ecosystem restoration on one hand, and increased wildfire occurrence rate, especially in Helan Mountain, on the other. Feedback from last Inner Mongolia stakeholder workshop recommends to promote nomadic stocking within an area belong to several herdsmen that can be organized into a small group. Another news from the workshop is a large camel conservation zone under construction because camel is an environmental friendship animal with very low breading cost.

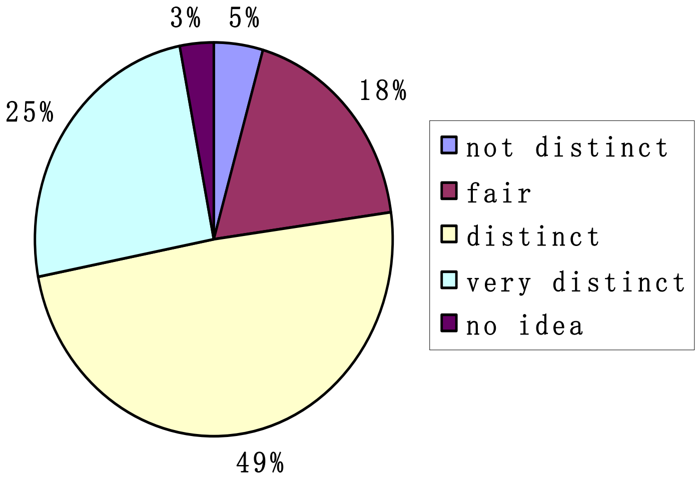

Figure 4.49: Statistics of 132 respondents on grazing-ban policy in 2006 survey in Inner Mongolia.

Enclosure or fencing has been widely employed in Inner Mongolia. Some experts indicated the importance of animal trampling and animal 'feces and stale' in keeping surface vegetation growth or regeneration. Some field experiments reveal that enclosure decreased local biodiversity. Thus, the enclosure or fence in grassland is seemingly not a natural management method. A regional or local nomadic pasturage appears again in some places of Inner Mongolia after removing their fences that belong to several herdsman habitants after general privatization in China since 1980s. It seems that limited stocking should be considered by policy-makers although many management problems would be met in practice. Besides, literature investigation and stakeholder workshop all provided us positive assessments on seasonal, rotational and limited grazing for grassland restoration.

Migration has become one of the most important official strategies in cope with climate change and environmental deterioration in Alxa League. Migration is often coupled with grazing ban and enclosure. However, only 52% of the respondents select 'distinct' or 'very distinct' in appraisal of the migration strategy (Figure 4.50). It implies that some problems exist in the policy implementation.

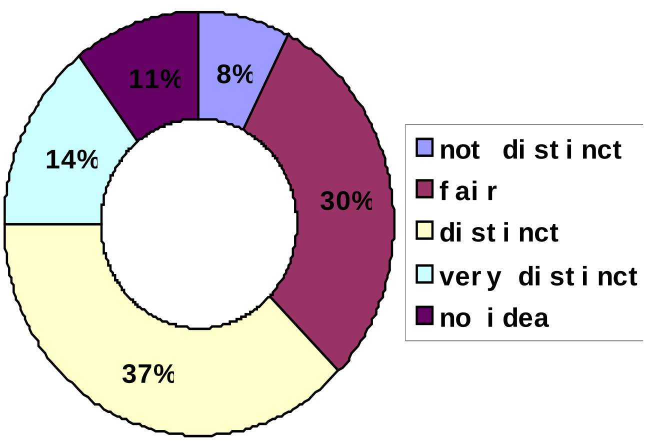

Figure 4.50: Statistics on effect of migration policy resulting from 132 respondents in 2006 survey in Alxa League.

One immigrant we visited in Ejina emigrant village was worried about her future because the funding usually comes from one or two projects which usually experiences 5 years. She asked how to maintain her family's life once the project ends. Moreover an officer told us that migration policies are different with location and migration year resulting from various projects and policies. It should be unique policy for emigrants in whole Alxa or a whole banner at least; otherwise psychological unbalance would appear among different groups of immigrants. In addition, a guarantee from SEE (NGO) indicated that the population excesses the caring capacity of some oases and led to rapid ground water drop and oases declining due to migration. A survey at Bantanjing emigrants in Ayou Banner of Alxa reveals that market fluctuation or inflation has seriously influenced their lives due to markup in oil and other goods (West, 2008). Consequently, to make a sustainable migration policy is one of the most urgent tasks for local policy makers. Recent news from Alxa shows that some modifications in migration policy have been made. Local authority would try to fine alternative livelihoods for immigrants in stead of compensation or subsides. Besides, it seems difficult to transfer them from herdsmen to peasants because they are used to be a herdsman in rangeland, other than a skilled farmer. So, good technique training on agriculture is very necessary for new immigrants.

Water-saving is a long-term strategy against water resource scarcity in Alxa League. Current water-saving methods and techniques are widely praised by stakeholders we visited. 62% of 132 respondents peach up the positive effect of spreading water-saving techniques on controlling land degradation and only 6% selects the term 'not distinct' in questionnaires. Questionnaires and Interviewees in the stakeholder workshops of Luanjingtan, Baronbieli and Bayanhot all confirm water-saving techniques in crop plantation, including plastic film mulching and using water-saving varieties. However, there are series of problems in cope with water resource shortage, such as insufficient funding on managing irrigation facilities, which support application of various water-saving techniques. So, financial and market instruments are necessary for keeping implementation of water-saving techniques. On the other hand, our numerical simulation also reveals that over-irrigating widely exists in maize plantation over Alxa League. This should be told to local farmers and teach them how to make optimal irrigation in farming. Water price adjustment is also an effective method in controlling water use in civil construction, tour and restaurant. And official water-taking permission was issued for controlling and monitoring large-scale extraction of ground water or river water for industry and mineral uses.

Heihe River reallocation has become a successful case in coordination of the water use in up, mid- and lower reaches of a river in order to reduce the water use conflicts and protect ecosystem in a river basin. On the other hand, our field work reveals that stakeholder's perception and awareness is still very low in Heihe River basin. So, training and environmental education should be promoted in the region. Moreover, in-depth interviewees asked to make legislation on water use, water right and punishment regulations

The policy of farmland conversion (*Grain for Green* policy) has received good effects in Ejina Banner and piedmont of Helan Mountain in the past decade. 78% of 132 respondents select the terms 'distinct' or 'very distinct' in questionnaire. Remote sensing recognized that the forest cover rate over Alxa has kept increasing after implementing the policy. But there are little potential on farmland conversion in the region now.

Grassland and forest rehabilitations have received great achievements in ecological restoration in Alxa League, as well known. This policy comes from a portfolio of adaptation policies, such as grazing ban, enclosure and migration. One of common problems is absence of sustainable funding or economic mechanism that supports the adaptation practice in a long period. Secondly, proper grazing should be allowed in order to keep vegetation refreshment and reduce excess liter accumulation, resulting from our interview in depth and academic studies. Besides, rapid rat population increase has become another factor that destroys grassland due to absence of animal trampling and natural enemies with climate warming.

Shelterbelt woodland construction had become one of widely arguable questions in China. A lot of trees planted early died or withered away due to improper species used, such as poplar. A director of local forestry office told me that they use local species in woodland plantation now. Aerial seeding is not a familiar adaptation way against vegetation degradation. Only 43% election rate of 132 respondents guess that it is of distinct or very distinct impacts on ecosystem restoration, and about 17% said no idea about it.

Artificial rainwater has been implemented for many years, but how to examine its effect is still an open question in the world. It is strange that 51% election rate of 132 respondents conjecture that it has distinct or very distinct effects on environmental amelioration.

The population pressure is a serious problem to oases where emigrants increase rapidly. A new policy appears in the Eleventh Five-Year Plan of Alxa League, in which outside immigrants are forbidden. The annual reports of Alxa League shows no significant increasing trend in population evolution in recent years.

Besides, clean mechanism development (CMD) is listed in the Eleventh Five-year Plan of Inner Mongolia, and the projected wind power would reach 0.3 million KW. However, the largest wind power plant in Inner Mongolia as well as in China is established in Huitengxile of Chaharyouyizhong Banner of Wulanchabu League (Inner Mongolia energy plan, 2005), and as estimated wind power output will reach 3 million Kilowatt by 2015. Wind and solar power are greatly promoted in Alxa too. A projected wind and solar power would reach one million Kilowatt by 2010. A wind power plant projected in Wuliji township of Alxa could provide an electricity output of 0.2 million Kilowatt after its establishment. As for personal or familiar level small wind turbine and solar panels are widely used over Alxa region. But current problems are their high prices and low quality complained by local users we visited. In fact, it is difficult to repair them if broken, because of no corresponding services in Alxa League. So, compensation and related services are necessary for locals if promoting to use clean energy in the poor region.

Figure 4.51: Huitengxile wind power plant (left) and solar heating (West, 2008) in Alxa League of Inner Mongolia

4.9.5 Challenges and recommendation

There are opportunities for Inner Mongolia to make further adaptation and mitigation measures and implementation owing to new institutional settings and a series of policies issued at national level to cope with climate change in recent years. However, climate change is not currently a key word in any government policies or documents at local level. Changes in temperature/precipitation or severity of extreme weather or climate events are not mentioned in Alxa's recent 'Eleventh Five-year Plan' document. By contrast, the central government has listed climate change adaptation and mitigation as an important measure in its 'Eleventh Five-Year Plan' and other major policies related natural resources and environmental management. Terms like sand storm and desertification are frequently used in those government documents because those phenomena are much more obvious in the region. Being asked if they are willing to take action upon solid information on ongoing and future climate change, local senior officers said that they would form a coalition of all involved government departments to adjust policies against the impacts of climate change if they understand climate change better or are asked to do so by central or provincial government. Fortunately, more and more funds from the state government or provincial government are investing on local adaptation and mitigation projects, such as water facility update, agriculture structure adjustment, energy-saving and emission reduction, environmental protection, migration, weather modification, forest and grassland rehabilitations, animal herb base establishment, etc. Correspondingly environmental education and social learning on climate change should be promoted for enhancing the capacity of climate adaptation in local stakeholders.

Challenges come from policy making process and institutional setting. Participatory exercises should be considered in local policy making. There are generally two types of policy-making processes, i.e. from top to bottom and otherwise from bottom to top, in China. The later refers the People's Congress system stretching from county level to national level. So, the 'bottom' (county) is not real bottom in administrative settings of the society, instead of the village. Over 80% of the farmers and herdsmen interviewed have noticed the declining of water quantity for irrigation and drinking, as well as increase of natural disasters such as severe drought, hot wave, and pest hazards. However, only few of them recognize that climate is changing. They wanted to express their concerns on the issues and ask governments for help if meet hazards, but the communication channel for farmers or herdsmen to express their concerns is local community leaders who have chance to reports those to up-level officers. Village management committee is only the self-organized institution responsible for community affairs. The head of the committee or village is elected by villagers in democratic way. The villagers, including farmers, herdsmen and immigrants are real actors in climate change adaptation. Thus, their participation in local policy-making process can not be ignored. To promote their environmental awareness is the duty for government and scientists. This can be enlightened or initiated through social learning and training. In general, villager head is the only one who can transfer the suggestions or ideas or the difficulties of the habitants to up-grade administration. Hence, how to elect a village head and organize effective management committee in a village becomes fundamental point in institutional setting. Nowadays, village heads and village management committee are democratically elected by villagers according to the lows that passed by the people's Congress of China. Hence, the institutional settings should be strengthened in village level. SEE (Society Entrepreneur & Ecology, NGO) has played an active role in establishment of village committee and democratic election to village head in Alxa League. SEE has lunched various projects in village level, including natural conservation and community development projects, scientific research projects, environmental education and training projects, and international cooperation projects. Those are usually funded by SEE or partly by the state or other international NGOs. One of key SEE project regulations asks for villager's participatory in co-funding and implementation of SEE's project in avillage, in addition to SEE guarantees. After In-depth interview to SEE we learn that SEE's strategy in ecological protection is also a very good model in climate change adaptation. Hence the government may do climate adaptation practice in village level together with NGO's. Besides, a guarantee of SEE recommended that both two types of policy-making strategies should be jointly employed in environmental policy-making processes in local or banner level.

Infrastructure construction is a fundamental strategy in cope with increasing extreme climate events. Governments are trying to respond to those requests by providing more specified weather forecasts and by co-paying agricultural insurance. Local meteorological bureau initiated a rapid warning system with cell phone text message for 3 Yuan/month (1 USD = 7 Yuan) to cover torrential rain, strong wind, sand storm, and hot wave in 2006. It has been very effective so far as most of farmers and herdsmen use cell phone in Alxa League.

Insurance for extreme weather and climate events is not widely covered in agricultural sector in the region. The main obstacle is that insurance companies are unwilling to face severer and more and more unpredictable natural disasters dominated by drought, sandstorm, frost, hot wave, and pests or diseases. In an experiment project, an insurance company known as Dadi Co. works closely with local government to insure corn production influenced by multiple disasters. Here local government provided co-payment (government covers 80% of the premium) for farmers and compensation from insurance company is up to 1000 Yuan/*mu*, varies according to actual loss. This is really a practical way against high-impacts weather and climate extremes.

Economic structure adjustment is a key measure in environmental amelioration, In the past five years, one of the major directional policies of Alxa government is to greatly reduce the share of primary industry (i.e. agriculture and livestock management) and to provide its residents with alternative livelihoods by boosting chemical and mining industries. Currently, rangeland counts for 1/3 of land area or 90,000 km^2, official statistics show a livestock population of 2,200,000 and herdsmen population of 30,000. According to the development plan of Alxa, by 2010, population living on livestock grazing will be further reduced to 10,000, or 3.7% of total population, while livestock population will be reduced to 2,000,000, including 1,000,000 in fence and 1,000,000 grazed on grassland. The government plans to reduce the numbers to 10,000 by 2010, mainly by providing job opportunities in coal mining and chemical industry sectors that developed rapidly in the northeast Alxa in recent years.

Market mechanism should be promoted further in adaptation strategies in such a harsh poor region. Deserticulture (Sandy agriculture) is a kind of desert green agriculture and shows a great potential in combating desertification and poverty for local residents. Several companies have invested a lot to plant economic and environment-friendship species in the deserts or semi-deserts together with local residents. They plant Cistenches, Licorice, Grapes, etc. and have made good benefits from them for both companies and local residents. It is no doubt a prosperous strategy in adaptation for such a poor area.

Tour is a sustainable strategy for promoting living standard of local residents and combating desertification. Various tourist resources exist in Alxa League. In its western Ejina, there are beautiful Euphrate poplar trees, red willow, blue Juyan Lake, historic sites of Juyan culture and Dongfeng Space Base; in its mid-area (Ayou Banner), The Bandan Jaran desert exploration has drowned more and more attention in China; and in its east part, Azou Banner, the sightseeing sites are Tengger desert, Helan Mountain conservation zone, A moon-like lake in Tenger desert and Jilantai salt lake, etc. To develop tourism is obviously a green way for alternative livelihoods of immigrants and local residents.

In conclusion, there are still challenges and opportunities existing in current and ongoing adaptation and mitigation policies for economic and social developments of Alxa League. Both poverty alleviation and adaptation should be jointly considered in policy making in such a harsh area resulting from the Inner Mongolia case study. Adaptation and mitigation is a systematic engineering combining varies of economic sectors and human dimension. So, how to make trade-off among climate adaptation and mitigation and economic development is a key point mainstreaming into regional policy making. The case is merely a small step toward this direction at local and regional scales, but more work need to do basing on what we have learnt from interaction with local stakeholders and scientists from both China and Europe. The coalition from China and European perspectives has lead to many new findings and recommendations for sustainable development of Alxa League in cope with climate change. The results and policy appraisal methods used in the case study could be employed in other cases with dissemination of ADAM project achievements and knowledge in China. This is helpful in understanding climate change and human adaptation strategy at different levels in different counties.

4.9.6 Reference

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5 Tisza River Basin background studies

5.1 Conclusions final workshop

Adaptation to water extremes - summary of findings from the experts' workshop on adaptation to floods, Budapest, 8-9th September 2008

Adaptation to climate change related weather extremes is typically location specific and needs to involve local stakeholders. The workshop of adaptation options focused on flooding and water issues in the context of the Hungarian Tisza river basin. It was held, in order to compare and evaluate adaptation options. Thirty-six Hungarian and international experts took part in the workshop and discussed a catalogue of 36 adaptation options. Adaptation options had been determined and described before the workshop in cooperation with work package A1 (in particular the work on the adaptation catalogue). Barriers and opportunities for the implementation of options in the Tisza river basin were identified.

Objectives workshop:

- Discuss options in the catalogue for a concrete case (focus on Hungarian river basins & the Tisza river basin in particular)
- Derive a list of promising adaptation options together with the conditions for their implementation
- Derive general conclusions on adaptation (options) that could be used as lessons on the European scale

Participants of the workshop agreed that certain level of risk has to be accepted. They saw risk management as the dominant approach. The participants indicated that to lower flood risks, and protect life and property should be the main goals of adaptation options. However, they were also concerned about related environmental and ecological effects of the options, e.g. negative effects of a particular type of reservoirs on fish. Concerns about costs of options and overall impacts on the market (particularly – local markets), jobs, eco-tourism, and agriculture were also expressed.

Changes in land-use planning and management were ranked as the most promising options. Low impact on the environment, supporting natural retention processes and extensive agriculture were mentioned as the crucial elements of the options representing changes in land-use planning and management. These options have relatively positive impacts on both local environment and local population.

The participants expressed that the integral river basin area approach is the most adequate for adaptation. The basin scale level is a crucial reference point for any action and analyses. It included transboundary issues. For the Tisza river the efforts have to be coordinated internationally since the river basin areas is located in four different countries. A complication here is that regulation differs between the countries and trans-boundary interests are conflicting, e.g. water retention and release upstream conflicts with downstream droughts management. Various instruments, especially incentives were identified as stimulating catchments scale coordination of adaptation efforts. The INTERREG program was given as a potentially good example in this context.

It was emphasized that adaptation options are implemented in portfolios and within existing institutional and socio-economic settings. Adaptation requires space for adjustment of policies to local conditions. It was felt that European level directives need to give general guidelines, while a portfolio of options must be determined by the local conditions. This relates to the uncertainty about climate change impacts. Measures should be flexible so that they allow adjustments to local weather extremes. Also a multi-sectoral approach is needed. Currently there is practically no cooperation and exchange between different ministries and with water authorities. Cooperation across sectors such as agriculture, transportation, forestry, education and nature protection has to be facilitated.

Different, often contradictory approaches, interests and mental models, specific for particular groups of actors involved in adaptation were seen as a significant obstacle to reach common understanding about a course action.

5.2 Background of Tisza river basin research

The Tisza river basin has a unique role in the Great plain in Hungary. It has transported water and nutrition and provided ecological services over centuries. Its water level fluctuations and flooding are an important driver of production systems in the floodplain that support livelihoods (Bellon, 1974, Somlyódy, 2006). The water and land management has changed several times in the last 250 years (Werners et al, 2009b, see also Section 2.3). To understand the key drivers of adaptation in the region the project team of the Tisza regional case study identified two appraisal questions for the Tisza area:

1. *What institutional setting and legal framework facilitates mainstreaming adaptation & mitigation options into integrated water and land management in the Tisza basin?*
2. *What sustainable land and water use pattern supports adaptation & mitigation in the Tisza basin?*

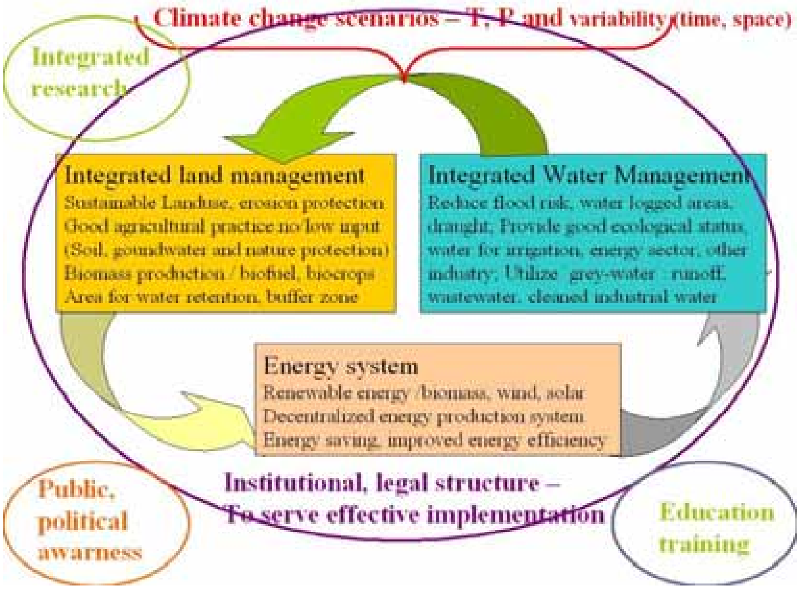

Figure 5.1: The approach for the Tisza valley case study in ADAM

In our analysis we have defined several constrains and opportunities for climate change adaptation (Table 2.5), which can be grouped into the following main research themes:

- **Adaptation in agricultural production** – both at small scale and large scale in integrated land and water management. The research performed in the frame of ADAM project has focused on the analysis of the potential impacts as well as the land utilization options under different expected climate regimes; demands for bio-fuel productions. Wine growing as a more robust land utilization option has been analysed to present potential alternative agricultural production systems and management options in light climate change (see Section 5.3, 5.4 and 5.5)
- **Institutional setting in land and water management.** Level of participation and transparency in the decision making process – emphasising the role of local farmers and land owners, local and regional, national governmental representatives (councils, authorities, research groups) and non governmental organizations (eg. churches, civic groups, individuals). Assessing procedures, informal roles and cooperation mechanisms (see Section 5.8)
- **Ownership** of key production capital – such as land, forest, grasslands, equipments-, and most important utilization rights – fishing, hunting, grazing, managing water system (see Section 5.9)
- **Flexible financing mechanism** – to support small and regional scale adaptation processes and to develop synergies between producers and customers at local and regional scale. The importance of small scale funding mechanisms was identified in the UNDP –GEF Tisza biodiversity project, resulting in a micro grant scheme. The implementation of the design got support from the ADAM project team to incorporate climate change adaptation goals with landscape revitalization and rural development objectives (see Section 5.10).

5.3 Climate impacts on main crop yields, risk and adaptation

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5.3.1 Agro-ecological potential of Hungary

The main object of the study was to determine the production potential of a cultivated region, depending on the natural environment, meteorological effects, soil properties, water supply, the genetic properties of the plants, as well as some adaptations of the environmental factors (amelioration, irrigation). The agro-ecological potential was calculated, assuming that the advanced production circumstances (technology, varieties etc.) do not change significantly in the next two decades. The factors considered in the study are shown in Figure 5.2.

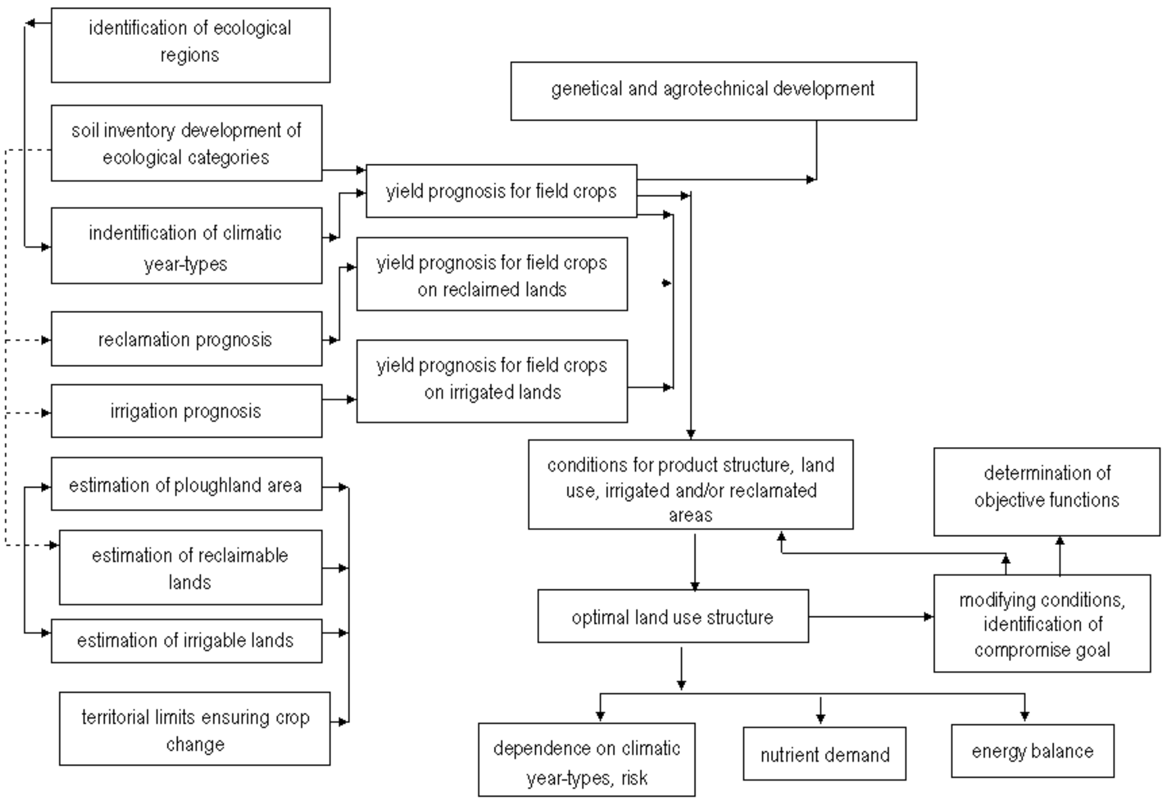

Figure 5.2: Factors in the agro-ecological potential assessment

The potential production was calculated for several types of cultivation. In what follows we present our results for field crops because crop production plays a key role in the Hungarian economy.

The ecological factors that were considered are:

a) characteristics of natural geography,
b) meteorological conditions,

c) soil properties,
d) hydrological conditions and
e) genetics.

First, according to the natural and economical characteristics, Hungary was divided into 35 agro-ecological regions, according to environmental and climatic factors. Meteorological conditions were taken homogeneous within the regions and described by a large number of meteorological parameters. Data were collected over the baseline period 1951-1975 for each agro-ecological region.

Figure 5.3: Agro-ecological regions

The most important field crops were selected (wheat, maize, winter and spring barley, rice, rye, alfalfa, red clover, sugar beet, potato, soybeans, sunflower and fodder peas) and were considered separately in the model. The production data of the crops for the baseline period were collected. Some multivariate statistical methods as well as expert opinions on climatic dependency of the crops were used in the selection of the characteristic meteorological parameters. Using production and meteorological data the climatic year types dry/warm, dry/cold, wet/warm, wet/cold for each region were determined (Table 5.1) by cluster analysis. The averages of the characteristic parameters of the climatic year types were determined as the cluster centres of the classes. The character of the variability of weather over a time period was analysed statistically by the climatic year type method. Each year type was characterized by its characteristic parameters involving appropriate functions of precipitation and temperature data during the vegetation period as well as by its probability of occurrence.

The ecological regions were then further divided into soil mosaics according to the quality parameters involving soil and hydrological conditions. 31 different soil types and more than 200 soil mosaics were considered.

Table 5.1: Climatic year types in Hajdú-Bihar County, Hungary

Maize			
	precipitation	effective temperature sum	frequency
	summer half year		
A dry – cold	300	1260	28
B dry – warm	200	1400	12
C wet – cold	530	1210	16
D wet – warm	300	1500	44
Winter wheat			
	April-May	May-June	
A dry – cold	70	450	40
B dry – warm	65	550	16
C wet – cold	140	365	12
D wet – warm	120	490	32

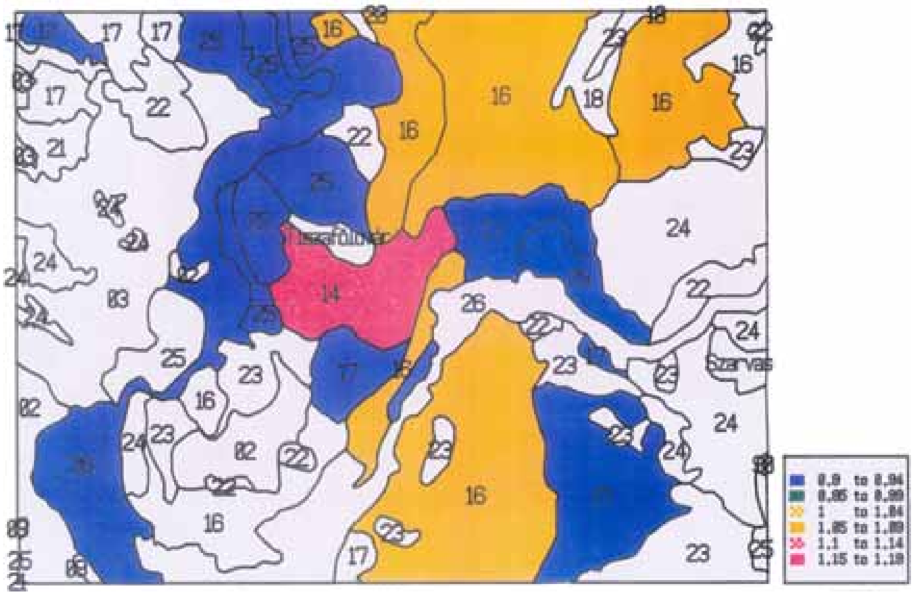

Figure 5.4: Relative productivity of sugar beet by soil types

A special study was executed on the expected development of the genetic potential of the main crops. Then the expected production of the 13 main crops was calculated for each year type. The main achievements of the assessment were:

- the description of the relationship between land use pattern and the required production (social demand);

- the characterization of the dependence of land use patterns and production on the level and schedule of investments (e.g. irrigation).

Table 5.2: Crop productivity for soil type and climatic year types in Hajdú-Bihar County

Maize					
soil types	climatic year types				expected value t/ha
	A	B	C	D	
14	7,4	7,1	9,1	9,6	8,6
16	7,4	7,1	9,1	9,6	8,6
17	6,1	5,9	7,3	7,9	7,1
23	4,8	4,7	5,8	6,4	5,7
24	4,8	4,7	5,8	6,4	5,7
25	6,1	5,9	7,3	7,9	7,1
Regional average					8,0
Winter wheat					
2	3,5	3,3	4,0	4,0	3,7
14	6,0	5,9	6,7	6,8	6,3
16	6,0	5,9	6,7	6,8	6,3
17	5,7	5,6	6,4	6,5	6,0
22	4,2	4,1	4,7	4,7	4,4
23	4,9	4,9	5,5	5,5	5,2
24	4,9	4,9	5,5	5,5	5,2
25	5,7	5,6	6,4	6,5	6,0
Regional average					6,1

5.3.2 The land use model

As a next step, a two-level hierarchical land use model was introduced. The basic objective of the modelling work was to determine an optional (or adaptive) land use structure in Tisza river basin depending on the soil properties, hydrological conditions, climatic factors, the genetic properties of plants, and economic and social background. The first level describes the situation in an aggregated form and is called *regional* model. The result of the problem gives an optimal regional allocation on investments and land use. Using this model, a global analysis of the crop production system can be carried out.

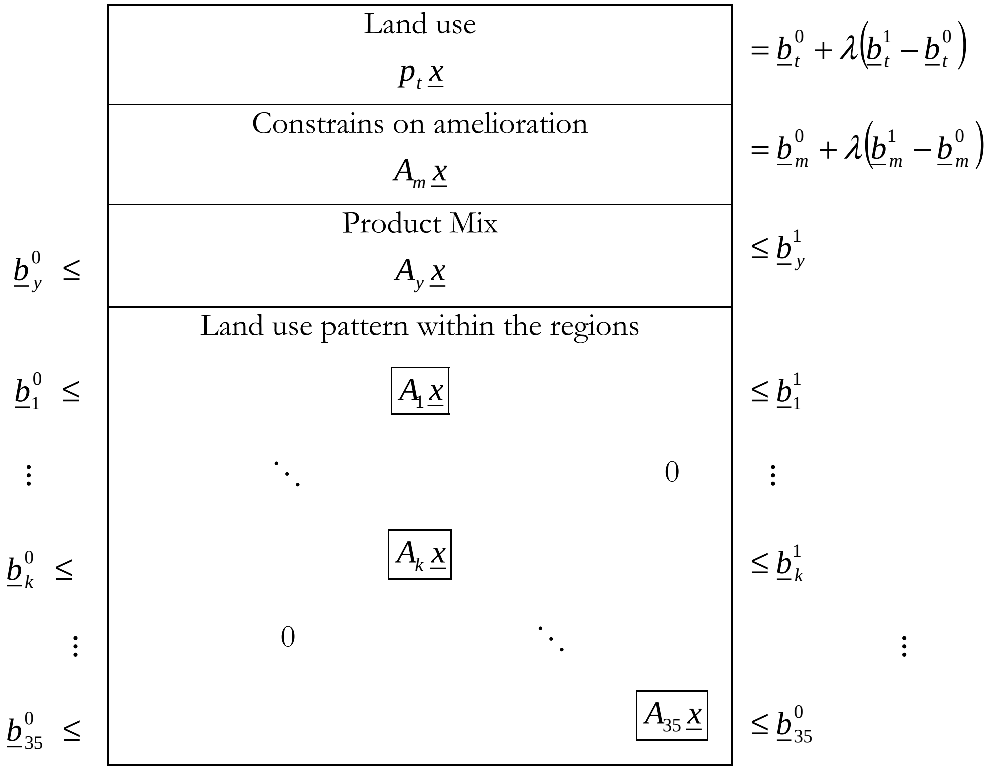

Figure 5.5: The structure of the two-level hierarchical model

The second model level serves a detailed analysis. It consists of four separate sub-models. The country was divided into four large regions and the crop production activity was described by separate models in each sub-regions. The structure of the sub-models is similar to that of regional model with their input constraints gained by the regional model.

The possible land use patterns were represented by the solutions of the system. The main problem here was to choose the criterion of optimality. The usual objectives of economical planning – like maximization of net income with minimization of costs – were not suitable as both costs (inputs) and products were counted in natural units. Hence, the objectives have to be formulated using some sort of price system. Therefore comparative value systems were applied and “Price systems” were only needed for the analysis of the system and not for the estimation of the profit. The comparative value systems were based on some indicators of the content of the products such as e.g. protein, energy, grain etc. Then the optimal product and land use structures under the different limitation levels were analysed.

$Fz \le x$	land use pattern
$Az \le b_1$	crop rotation
$H(u,z) \le b_2$	agrotechnical conditions
$Y = Gz$	output
$y_0 \le y \le y_1$	product structure
$(z,u) \in \Omega_p$	risk condition
$\Theta(y, u) \to opt$	objective condition

Risk conditions

$$\Omega_p = \{u \mid 1 - F(y; x; u) \le p;\ y \ge \alpha E(x, \xi, u)\}$$

Figure 5.6: The mathematical form of the land use model

The main steps of the work were:

- The determination of the homogenous soil mosaics and their characterization according to meteorology, hydrology and productivity. The basis of this step is the soil map of HAS RISSAC (Research Institute for Soil and Agricultural Chemistry of the Hungarian Academy of Sciences);
- Selection and downscaling of climate models with their scenarios;
- The characterization of the distribution function of crop yield (winter wheat, maize, sunflower) depending on the changing climatic conditions by simulation. We have not considered the possible genetic and agrotechological development; however we assumed a general yield growth.
- The assessment of risk according to the expected value and potential yield.
- The application of the land use model system.

The last two steps have been partially completed and will require additional work in the future.

The model system is linear, nevertheless, it contains

- real and integer variables,
- quasi stochastic elements (some risk conditions are formulated) and
- multiobjective factors.

The mathematical form of the model is shown in Figure 5.6.
The structure of the model system is shown in the Figure 5.7.

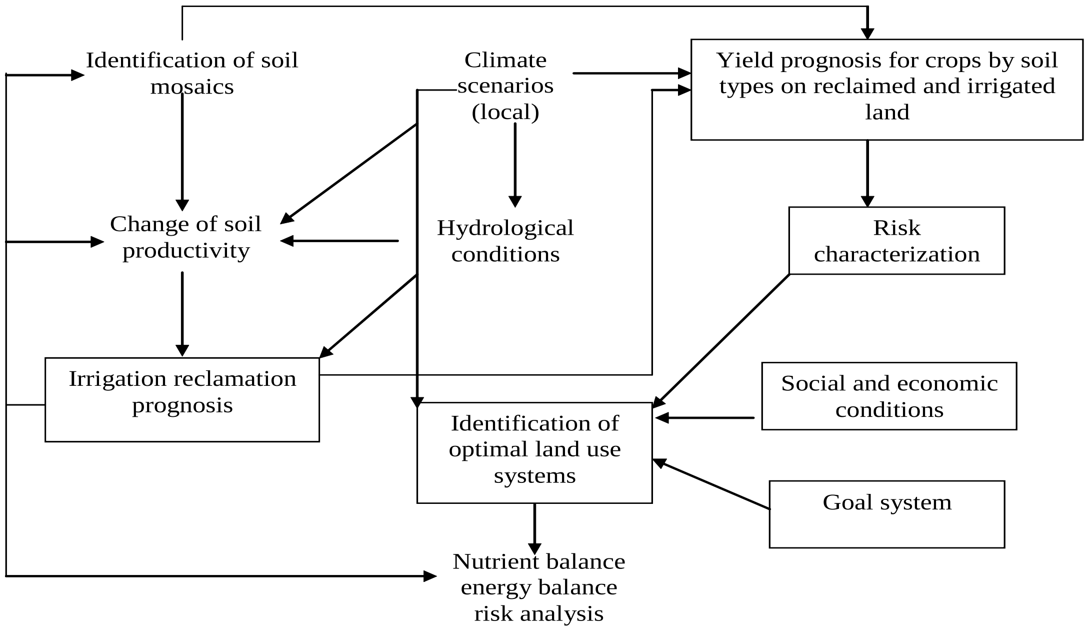

Figure 5.7: Structure of the land use model system

5.3.3 Climatic conditions and future scenarios in Tisza region

In order to evaluate change in temperature and precipitation at high resolution we analysed the outputs of the regional climate model RegCM3 which was originally developed by *Giorgi et al.* (1993a,b) and further modified as described by *Pal et al.* (2007). The applied spatial resolution of this model is 10 km, which is the highest resolution that can be reached at present with the hydrostatic RegCM3 regional climate model. Some modifications were made to RegCM3 discussed in Torma *et al.* (2008). The applied scenario was A1B which corresponds to a moderate increase of atmospheric CO_2 concentration (*Halenka*, 2007). Mean seasonal temperature and precipitation changes were determined for the target period 2071-2100 relative to the reference period 1961-1990. According to these simulations, temperature increase is expected to exceed 3°C in summer and autumn in the Tisza river basin. In winter, larger warming (exceeding 3°C) is expected in the northeast part of the region than in the southwest part. The smallest temperature increase is expected in spring, i.e. 2-3°C only. As a consequence of regional warming, the warmer air may contain more moisture, which can raise the frequency of heavy rains.

Precipitation is one of the main issues of this region. Previous studies (PRUDENCE, Christensen et al., 2007) concluded that Hungary lies on the border of opposite expected precipitation changes: the Mediterranean region where drier conditions than the current climate are projected, and northern Europe where wetter climate is expected. Precipitation projections of RegCM3 suggest change is season dependent in the Tisza basin, namely:

(i) precipitation is expected to increase in winter and autumn by about 10% and 5%, respectively, and

(ii) it is projected to decrease by about 15% in summer and 5% in spring (all on spatial average).

In the southwest part of the Tisza region the summer climate can be drier by more than 20% relative to the reference period. In summary the climate of Tisza watershed region is projected to become warmer by the end of the 21st century compared to the current conditions. Furthermore, summers and springs are expected to become drier in the future while winter and autumn tend to become wetter.

5.3.4 Climate impacts on main crop yields, risk and adaptation option

Background reading with this section: Erdélyi (2008)

Climate determines agricultural production. Even slight changes of meteorological parameters can have serious impacts on agriculture. The more frequent the extreme weather events are, the more uncertain crop results. The climate change impact study of the most important cultivated plants was executed for the time interval 1951-2005, split into twenty-year intervals. First, the subjective distribution functions were defined for the five times twenty years. The strongest production risk increase was detected in the last two time intervals, which was illustrated by using different efficiency criteria (Erdélyi, 2008). By applying a more general stochastic efficiency criterion, we showed that the production risk of the crops has increased, independently from the rate of risk aversion of the decision makers.

Climate variability, especially precipitation, increases crop yield variability. We analysed the temperature and precipitation demands of the plants in each phenological phase. We examined the frequencies of extreme temperature values during the growing season and their effects to the plant phenology and yield. For the simulation we used the 4M model which is based on CERES model adapted to Hungarian circumstances. The starting dates of the phenological phases of plants are valuable indicators of climate change because plants are sensitive to temperature and phenology is mostly easy to observe. The study of the change of the length of phenological phases can help us in understanding climate change impacts and adaptation possibilities.

The simulation results for the middle of this century including adaptation options show about yield increase of about 18% compared to the reference period, with increasing variance. Efficient plant growing requires the harmony between biological, ecological and technological factors. Efforts should be made to encourage varieties, which are not very sensitive to the shortage of their needs and the variability of the growing season circumstances. Adjusting to climate change (including climate variability and extremes) means to moderate potential damages as well as take advantage of opportunities or cope with the consequences. It is partially a spontaneous or autonomous response but it also depends upon policy and planning. This means that not only the plants can adjust to changing conditions (which might be a very long process) but we can help by introducing interventions. Adaptation and response strategies are particularly relevant nowadays because of more frequent extreme weather events.

Crop development and survival depend strongly on the timing of sowing. For example, if the plant is strong enough before the beginning of winter, it can benefit from winter precipitation, and its development is supported in spring. Therefore early sowing has adaptation advantages. Besides meteorological circumstances on the field are better in early autumn. We have analysed the biomass and grain mass change of winter wheat and maize. We used a crop model for finding an adaptive strategy in order to increase the yield. The simulations were run with the routine date of sowing and four other sowing dates as inputs. For both biomass and grain mass quantity the simulation results are very promising in case of both plants for the two weeks earlier sowing date. The average yield increase in case of winter wheat is close to 6% in case of the two-week earlier sowing date. In case of maize the increasing yield is not that significant, nevertheless, smaller coefficient of variation was detected. In summary we can say that the two-week earlier sowing might be a good adaptation strategy. This strategy is good for the plant because the growing period could avoid the most unfavourable drought condition and the enhancement of ripening is more probable.

Irrigation and its timing is of high importance in arid areas. Therefore first we have traced the biomass change through the phenology of the plant and determined the dates when the biomass quantity was decreasing due to precipitation shortage. We applied the model for two different irrigation strategies and showed that with appropriate adaptation strategy we can benefit from climate change. We have used different climate scenarios and a baseline scenario for the reference period as weather inputs. The results of the first irrigation strategy (two times 50 ml/cm^2 in July) for corn show 1.63-2.2 times more production for the middle of the century and 1.37-2,59 times more production for the end of the century. Simulations for the second irrigation strategy (two times 50 ml/cm^2 in July and once 50ml/cm^2 in August) predict the possible yield increase 1.38-2.79 and 1.76-2.66 in average.

We have also analysed the proportion of the parts of the corn plant, the grain development and grain mass. We could detect not only the shift of the period of grain development but also that climate change may have a good influence on grain mass of the plant due to increased CO2 levels (Veisz *et al.* 1996). The use of some secondary biomass with grains for biofuel production could be a good strategy in mitigation of global warming and saving a part of maize production for food and feed supply (see also Section 5.5). The biomass of the plant is expected to increase in the future as does the grain mass. In addition, the simulation results show that the proportion of grain mass in the overall biomass (the harvest index) is expected to increase. The average production is predicted to be higher in the future and the same holds for the maximum production in the two-week earlier sowing case. However, the coefficient of variation is also expected to increase which means increasing risk and uncertainty. Modelling is useful in adaptation strategy development. It can decrease the uncertainty that the change could bring and we can concentrate on how to benefit from climate change.

An additional research study analysed the climatic conditions for maize growing in Hungary based on the Hadley Centre's HadCM3 model with A2 and B2 emission scenarios over different 30-year time periods (Bartholy *et al.* 2007). Results show that in the Upper Tisza region the potential vegetative period (Temp. > 10°C) could be longer by approximately 25 days in the middle of the century and about 40 days at the end. In the near future the longer potential vegetative period and increasing effective heat units would be favourable to grow maize varieties with 2–3 further FAO groups, which have a higher potential yield, but the precipitation could be a limiting factor. During the observed time interval time a drastic increase of the heat units can be observed with a serious decrease of precipitation. The results of clustering the climatic year types show a continuous shift: from about 2030 the minimum heat unit values becomes equal to what are high values nowadays.

5.3.5 Viticulture challenges under changing climate in Hungary

Background reading with this section: Ladányi (2008)

Viticulture is an economically important agricultural production sector in the Tisza region. In this paper we introduce the risk assessment method and show that the risk of grapevine production increased in Hungary in the past few decades and discuss the possible reasons. Climate change and its expected impacts on viticulture of Hungary are considered and the reasons and consequences of risk increase are explored. Following a synthesized analysis of international and national literature we determine weather indicators, which impact grapevine production. We describe how the trends of the examined indicators have been changing with time, using data management software. We derive the expected change of weather indicators under different climate scenarios. Finally we draw conclusions for Hungary and the Tisza region in particular.

According to the downscaled Prudence A2/ B2 as well as Tyndall A1/A2/B1/B2 scenarios we can expect the following changes in Hungary until 2070:

- Increasing mean temperature results in reduced winter dormancy and expected warmer and longer growing seasons and season's shift of 6-25 days, depending on location. Ripening will begin earlier during the hotter summer months. Higher temperatures at ripening may depress quality and will shorten the harvest window for premium quality wines. Suitable locations of the varieties, with which growers have long time experience are expected to be shifted northward, while the current grape growing regions may shift to another maturity type.
- Increasing winter-spring precipitation (A2: 0-37%, B2: 3-27%) and decreasing summer-autumn precipitation (A2: 3-33%, B2: 0-20%). Less water is likely to be available during summer, due to increased evapotranspiration and/or lower precipitation. Grapevines are mostly not irrigated in Hungary and susceptible to drought with negative effects on yield and quality (Schultz and Lebon, 2005). Yield/quality variability is likely to increase creating a higher economic risk for the producer.
- Increased atmospheric CO_2 concentration can be beneficial to plant growth but some studies of the combined effect of higher CO_2 concentrations, temperature and solar radiation indicate that overall yield may be depressed (Schultz, 2000). Other studies suggest that in a warmer climate it is possible to ripen larger crops as there is more photosynthetic potential (Howell, 2001). Modelling results disagree about the effect of CO_2 on assimilate (sugar and starch) accumulation in the fruit, the timing of bud initialisation and flowering and the final composition of the fruit, enlarging the uncertainty and risk of production in the future (Tate, 2001; Taylor, 2004).
- More frequent and serious weather anomalies (heat wave, storm, wind, flood, hail) require more complex management against catastrophes and for already scarce water resources. Warming during also the dormant periods decreases the number of winter/frost days with more than 60%. Nevertheless, frost risk can increase because of early vegetation period start. The number of days with maximum daily temperature above 25 °C increases with 39% to 140-150 days in some regions and nowhere less than 120 days (according to A2 scenario).

- Changes in the presence or intensity of pests and diseases may render the current pest management strategies un-useful. Thus new technologies and management practices need to be put into action.

5.3.6 Spatial climatic analogy

Background reading with this section: Horváth (2008)

The climate that future scenarios project for a certain region may already exist somewhere else on the planet at present. Once identified, we can learn from these regions what the future climate is like and how to cope with it. Spatial analogy is a method that allows us to find regions that at present have a climate similar to what scenarios project for the future in a study region. In this research the analogous regions of upper-Tisza region were identified and found to be regions south of Hungary. The spatial shift is about 250-450 km in the next decades (2011-2040). By the middle of the century, it is expected to be 450-650 km. There is no detectable spatial analogue in Europe for the end of the century. There were different methods used to calculate the analogues, though they indicated the same analogous regions. The analogous regions of Tisza region are North-Serbia, Vojvodina regions, South Romania and North Bulgaria in the next decades, while they are South Bulgaria and North Greece in the middle of the century.

The inverse of the analogy method was also developed. The inverse method is appropriate for finding the regions, which have similar climate in the future as the studied region has at present.

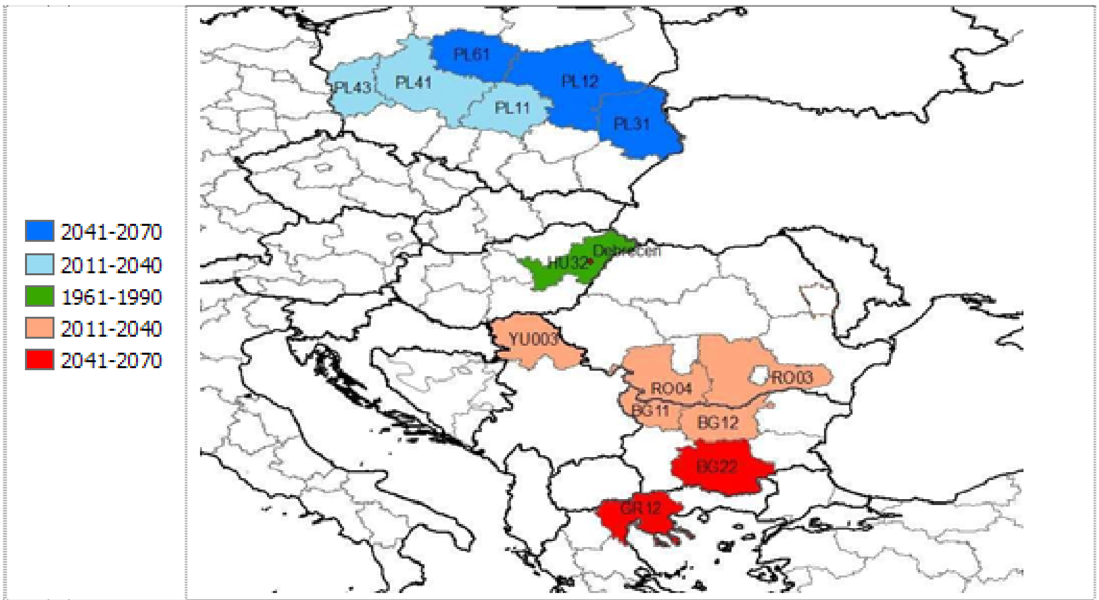

Figure 5.8: Spatial climatic analogue regions (NUTS2) (After Horváth, 2008).

Using the concept of spatial analogy, we can identify and compare the analogous regions in different ways. Land use, crop and natural vegetation data were collected from EUROSTATs and from CORINE database. The comparative data analysis indicated that the land use may become more diverse which is positive for adaptation. The ratio of forest and pasture may become higher as well as maize and wheat production. Of course land use depends also upon aspects such as elevation, topography and storm-track conditions, which have not been considered in the analysis yet.

Spatial analogy seems to be a good tool to understand and interpret the results of the GCM scenarios and the effects of climate change, and we want to go ahead in this research. More detailed analyses of the analogous regions can help us to adapt to changing climate. The method together with additional data of the analogous regions can provide information about climate change impacts on ecosystems, agricultural production, land use, cropping systems as well as on potential production, and on the possibility of (dis)appearance of crops, weeds and pests in the region. From the analogous regions we hope to collect different ecological, agricultural, economical, social or public sanitation data. We can study what kind of problems there are, and what the solutions are. We can learn how to solve the possible problems and develop strategies using experience of the analogous regions.

5.3.7 Discussion

Increased mean annual temperatures in Hungary, if limited to two or three degrees, could generally extend the growing season length. As the phenological phases depend on an accumulated heat unit, the phenophases could become shorter. Whether crops respond to higher temperatures with an increase or decrease in yield depends on whether their yield is currently strongly limited by insufficient warmth or it is near or little above the optimum. In Central Europe where temperature is near the optimum under current climatic conditions, increases in temperature would probably lead to decreased yields of several crops. Increased temperature could be favourable for example for grape; however, it is unfavourable for green peas and potato. Decrease of precipitation will become a limiting factor in agriculture.

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5.4 Diversification of land use to cope with climate variability

Werners, S. E., F. Incerti, M. Bindi, M. Moriondo and F. Cots (2007) Diversification of Agricultural Crops to Adapt to Climate Change in the Guadiana River Basin. In Proceedings ICCC 2007, Hong Kong.

Summary: Adaptation is gaining attention as an inevitable answer to the challenges posed by climate change. The increasingly uncertain climatic conditions, to which actors are exposed, are becoming a constraint for their well-being. This study looks at diversification of agricultural land use as a key factor in reducing risk and a means of coping with an uncertain climate. Borrowing from economic theory, the study illustrates how cropping patterns influence the expected revenue and risk. The standard deviation of the land use revenue is used as a proxy for climate risk.

Agricultural land use is associated with two competing land use and water management strategies in the Hungarian Tisza River Basin: intensive agriculture protected by flood levees and water retention areas with extensive cattle breading and orchards. To cope with flood risk, the Hungarian Government supports water retention and land-use change to replace or complement the prevailing intensive agriculture dependent on flood levees and drainage. Our analysis shows that revenues from agriculture are well adjusted to the current climate variability. Considering recent revenues, a shift from intensive agriculture to extensive cattle breading and orchards increases both the expected revenue from agriculture and the risk.

5.5 Energy crop potential in the river floodplain

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5.5.1 Biophysical aspects

One of the research fields in the ADAM Tisza case study in relation to „Land Use and Agriculture for adaptation & mitigation" was „Energy crops and their cost effectiveness in relation to adaptation & mitigation".

The Tisza plain in Hungary covers some 3 million hectares of which some 2 million hectares can be used for direct arable farming, and 1 million hectares for reduced agricultural and agri-environmental activities (Figure 5.9).

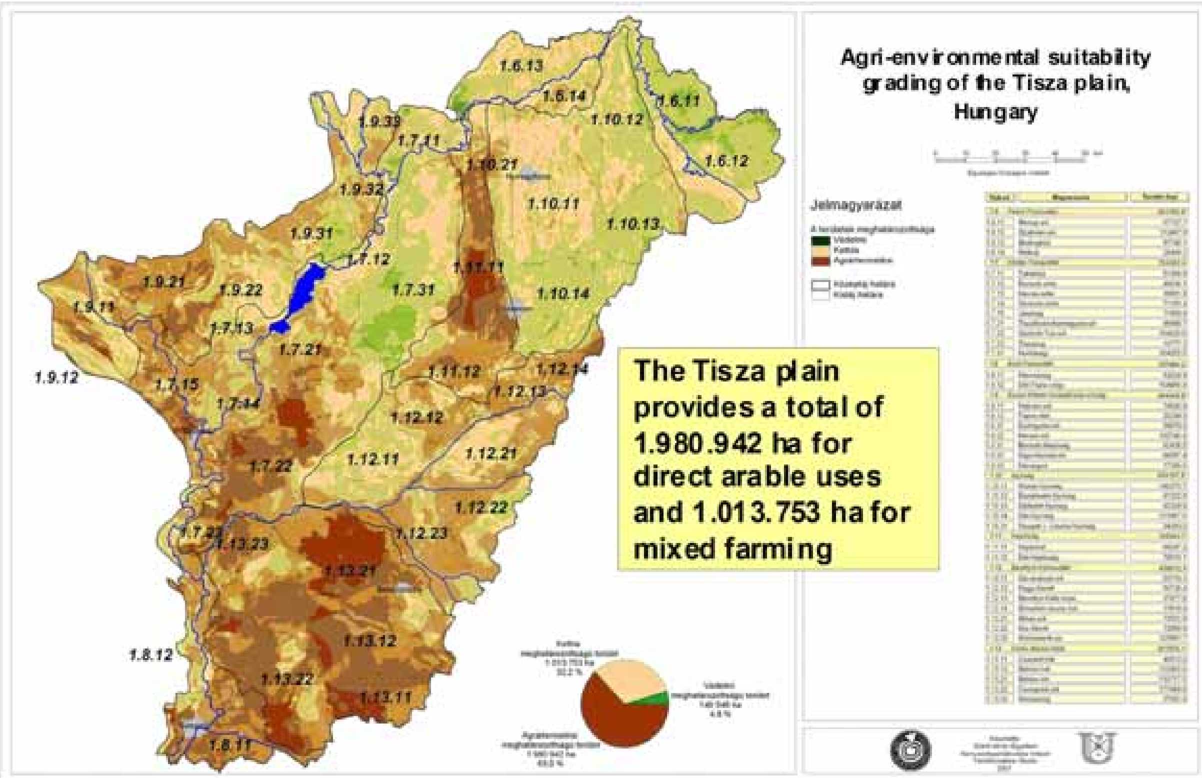

Figure 5.9: Agri-environmental suitability of the Tisza plain

The present land use systems in the Tisza plain are in transition induced by both social, economic and agro-ecological motivations. Serious attempts have been made by the national agricultural policy makers towards changing the cropping system. One of the fields of that is encouraged is energy crops.

5.5.2 Technical aspects

Agriculture in general and energy crops in particular is a most important field of renewable energy sources. There are three major fields within agricultural renewable energy resources: one is the biomass production for direct combustion and for indirect uses and further processing. The other is the bio-diesel and the third is the bio-ethanol production. The two latter ones belong to the target area of energy cropping. Two reasons support the development of these fields. Firstly, Hungary has very limited natural energy resources. The only natural energy resource is its agricultural potential, including the 1500 MJ/m^2 photosynthetical energy it receives that allow converting atmospheric carbon dioxide into various biological matters. Secondly, the highly variable global food market that is often resulting in food surpluses in this part of the world combined with the rather strict EU regulations regarding regional and national food production contingents, support looking for alternative crops. Energy crops are also considered a tool in mitigation of GHGs, especially CO_2 emissions. Fuels derived from agricultural energy crops may replace fossil energy sources. Photosynthetic carbon sequestration may be utilized in three possible fields (Figure 5.10).

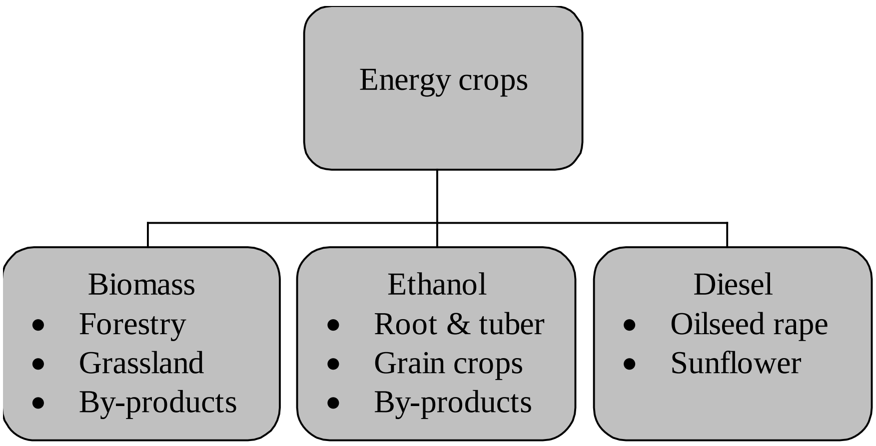

Figure 5.10: Main fields of photosynthetic carbon sequestration in Hungary (Jolánkai, 2007)

There are many problems with each of these fields (Berzsenyi-Lap, 2005; Hill *et al*, 2006; Jolánkai *et al*, 2005; Lawlor, 2002; Márton, 2005; Sárvári, 2005), including:

- Low energy conversion efficiency (1:1 to 1:6 maximum).
- Economic losses in comparison with conventional energy sources (fossil fuels, nuclear power etc).
- Deterioration of environment by abusing organic matter cycles. Exploitation of natural resources.
- Lack of sustainable long-term vertical and horizontal technology structures.

- Uncertainties in industrial by-product outputs and technology side effects.
- Counteracting of food security while producing energy crops on areas dedicated to food supply or when alimentary crops or edible grain yields are converted into bio fuels.

The three main fields of photosynthetic carbon sequestration (Figure 5.10) are all affected by the problems listed above, however in different ways and to a different extent. There are two characteristics that should be evaluated in all cases independent of the energy source: firstly the energy input (the energy conversion efficiency (NEB – net energy balance)), and secondly the economic viability in comparison with the cost of regular commercial energy. Figure 5.11 provides information on these characteristics.

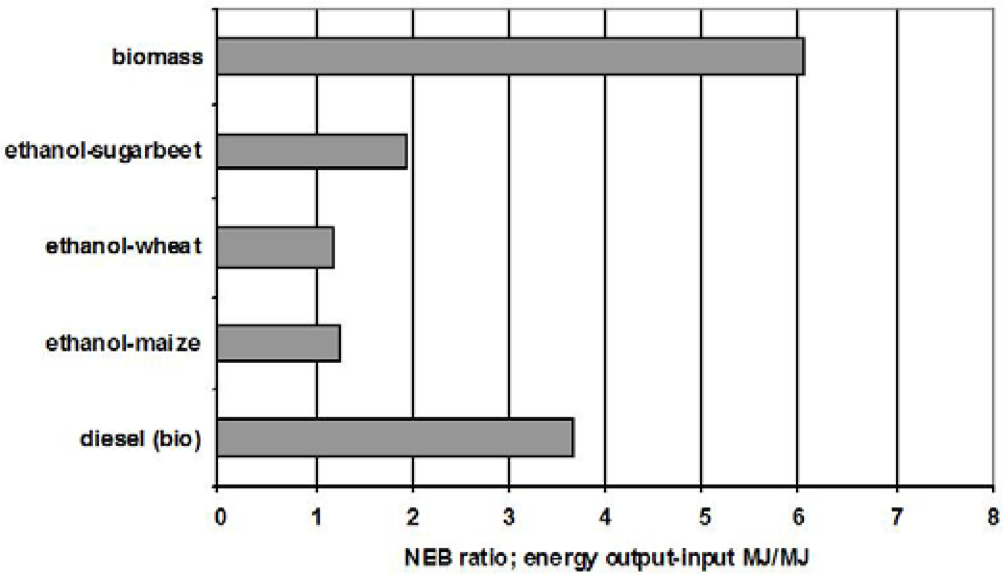

Figure 5.11: Energy conversion efficiency of some agricultural crops (Hill et al, 2006)

It can be seen, that there are considerable differences regarding the use of various agricultural crops. The highest efficiency was found in cases of direct and indirect uses of biomass, like in burning or fermentation. Biomass energy conversion can have a 1:6 energy input-output ratio. Bio fuels – bio-diesel and bio-ethanol – have much poorer energy return figures. Bio-diesel production has a 50-60 percent lower efficiency than that of biomass derived energy. The different bio-ethanol versions have the lowest NEB ratios. Depending on the crop species used, it is between 1 to 2 NEB ratio. Regardless of this low energy conversion rate, for two reasons ethanol production is considered a promising field of renewable fuel production. First, it has relative low production costs. Secondly, production uses safe and simple technology. Commercial large scale production of ethanol from almost any agricultural crop (like grain crops, root and tuber crops, fruits) and various farm and processing by-products has been quite common in Hungary since the mid nineteenth century. Nevertheless, today neither bio-ethanol, nor bio-diesel production is an economical alternative for fossil fuels, although rising oil prices may change this in the future.

In CUB coordinated research agronomic use of 24 potential energy crops has been studied (grain crops, legumes, oil seed crops, root and tuber crops and energy grasses). The potential production area and regional distribution have been identified (Fogarassy, 2000, Fogarassy, 2004; Jolánkai, 2008). Following the recent energy and food shortages in the world remarkable changes can be observed in the cropping structure of the region. Between 2007 and 2008, the area of the oil seed crops rape and sunflower has expanded with 24-32 % respectively. In addition there is the production of other energy crops and the renaissance of major grain crops. Cash crops, like sugar beet and potato, and fodder crops have lost areas.

5.5.3 Discussion

Although the agro-ecological conditions in Hungary and the Tisza region are suitable for efficient energy cropping that may contribute to the national energy supply, there are doubts as well. The expectations regarding energy cropping are presently too high. If only because the market for food and food products is improving as well.

The expansion of energy cropping will be influenced by two main factors. Firstly, the economic necessity induced by uncertainty of energy prices (Hungary imports the majority of its energy resource and all its motor fuels from abroad). Secondly, the investments made in energy production including refineries and power plants, which is highly depending on government and EU policies. Innovations and development depend on the institutional structure available. The following items have to be taken into consideration in the future:

- Support for national policies and strategies.
- Promoting farmer-centred research and extension.
- Improving rural infrastructure.
- Strengthening local resource management.
- Providing entitlements for food security.
- Establishing fair and secure land tenure.
- Reinforcing farmers' organisations and users' groups.

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5.6 Mitigation potentials of forests in the Tisza region of Hungary

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5.6.1 Introduction

The ADAM project studies strategies for adaptation to and mitigation of climate change in the Tisza river basin in Hungary served as one of the regional case study areas. The Tisza is a major river in central Europe, which originates in the Ukraine, in the Northeastern Carpathians, and flows into the Danube in Serbia. In between it passes Hungary, flowing through the extensive plains in the east and south of the country. Floods along the Tisza occur in spring, due to snowmelt in the mountains, but local floods in the upper river basin also occur in other seasons, due to heavy rains (Timár and Rácz, 2002a). It is expected that climate change will increase the incidence of problematic floods in the Tisza river basin, since wetter winters are foreseen (Bartholy et al., 2007). Paradoxically, also the incidence of severe droughts might increase, since higher temperatures and drier summers are expected too (Bartholy et al., 2007). The current river protecting system, based on the historical paradigm of 'protecting the landscape from the river', appears to contribute to the severity of these flood and drought events (Timár and Rácz, 2002a; Sendzimir *et al.*, 2008a). In the past, many bends in the river were cut off to the make transport on the river by ships easier. Further, the floodway of the river was made smaller by the construction of dikes. Before the construction of these dikes, the river was bordered by broad and spongy floodplains, of ponds, floodplain forests and marshes. The regulation of the river and the construction of dikes lead to a quicker discharge of flood water, but it also resulted in higher peak water levels during floods and it increased summer droughts (Timár and Rácz, 2002a; Sendzimir *et al.*, 2008a).

Forests and forestry can potentially contribute to the solutions of the river management problems in the Tisza river basin area. Afforestation in its upper basin area and afforestation on broad floodplains along the river might increase the water retention capacity of the river basin area, thereby preventing extremely low and extremely high discharges. Further, by storing carbon and providing biomass, forests can affect the emission of the greenhouse gas CO_2, and might mitigate climate change. Our study served a background study to this Tisza River basin case study and we focussed on this last aspect. The aim of our study was to assess potentials for mitigating climate change by forests in the Tisza region. Specific research questions were:

- How does the growing stock and wood production potential of the forests situated in Hungary and particularly in the Hungarian Tisza River Basin develop?

- What is the carbon sequestration potential of the forests in this region.
- How will afforestation affect carbon sequestration and wood production?

To answer these research questions, forest development was simulated with a forest resource scenario model, the EFISCEN-model. Three scenarios were applied: a 'base run scenario', a scenario of increased demand for wood products and an afforestation scenario. The 'base run scenario' was applied to study the development of the present forest area, under the current level of wood demand. In this scenario, a constant level of demand for wood products was assumed. In future, the demand for wood from forests might increase, for instance when biomass is used on a large scale as an alternative source of energy. In the 'increased demand scenario', a continuing and significant increase in the demand for wood was simulated. The 'afforestation scenario' was applied to study the consequences of afforestation in Hungary, and especially in the Tisza region. Since 1945, the forest area in Hungary has increased with 600 000 (Mészáros et al., 2005) implying an average afforestation rate of about 10 000 ha per year. In the afforestation scenario, we study the consequences of a continuation of the afforestation at this rate, and we further assume an extra afforestation of 5000 ha per year in the Tisza river basin area.

5.6.2 Materials and method

Input data

A description of the EFISCEN-model and a user guide can be found in (Schelhaas and al., 2007). This model has previously been applied to model forest development of Hungary (e.g. (Schelhaas et al., 2004). The input data of the simulations were based on forest inventory data from 2006. 1.859 mln ha of forest was included in the model. Based on these inventory data seven regions were distinguished (Table 5.3, Figure 5.12). The regions Northern Hungary, Northern Great Plain and Southern Great Plain were assumed to represent the Tisza River Basin area. The following 12 species groups were distinguished: Quercus robur, Quercus petraea, Quercus cerris, other hardwood broadleaves (including Fraxinus spp, Acer spp), Fagus sylvatica, Carpinus betulus, Populus spp and Salix spp, other softwood broadleaves (including Tilia spp, Alnus spp), Pinus nigra, Pinus sylvestris, other conifers (including Picea spp, Larix spp).

The growth functions of the tree species in the model were based on growth and yield tables. Regimes of felling and thinning were included in the model by defining for each age class a probability of final felling and thinning (Schelhaas and al., 2007). Final felling was defined by the minimum age for final felling, when forests have a probability of 10% to be felled, and by the age when the felling probability reaches 100%. The felling probability between these two ages is calculated by the model by interpolation. The thinning regime was defined by the minimum and maximum age of thinning. The final felling and thinning regimes were based on the inventory data and on the study by Schelhaas et al. (2004), and are presented in Table 5.3.

Figure 5.12: The seven regions distinguished in this study

Table 5.3: The regions and counties distinguished in this study

Regions	Counties
Central Hungary	Budapest Pest
Central Transdanubia	Fejér Komárom-Esztergom Veszprém
Western Transdanubia	Győr-Moson-Sopron Vas Zala
Southern Transdanubia	Baranya Somogy Tolna
Northern Hungary	Borsod-Abaúj-Zemplén Heves Nógrád
Northern Great Plain	Hajdú-Bihar Jász-Nagykun-Szolnok Szabolcs-Szatmár-Bereg
Southern Great Plain	Bács-Kiskun Békés Csongrád

Table 5.4: Regimes of final felling and thinning for the different species groups

Species	Age at which probability of final felling is 10%	Age at which probability of final felling is 100%	Minimum age at which thinning is possible	Maximum age at which thinning is still possible
Quercus robur	100	150	20	100
Quercur petraea	100	150	20	100
Other hardwood broadleaves	70	110	20	70
Quercus cerris	100	150	20	100
Fagus sylvatica	100	150	20	100
Carpinus betulus	70	110	20	70
Robinia pseudocacia	20	40	10	20

Populus spp & Salix spp	20	40	10	20
Other softwood broadleaves	40	90	10	40
Pinus sylvestris	50	90	20	50
Pinus nigra	50	90	20	50
Other conifers	50	90	20	50

Scenarios

The input data were used to simulate forest development for the period 2006-2056. Three scenarios were applied: a base run scenario, a scenario of increased demand for wood products and an afforestation scenario (see Introduction).

- In the base run scenario (**BR**), the annual harvest level was kept constant, at the level of the year 2006. This level was based on the FAO statistics on the production quantity of roundwood (http://faostat.fao.org/site/626/default.aspx#ancor). An annual harvest level of 5.913 mln m^3 of roundwood was assumed and this annual harvest level was kept constant during the whole simulation period. 67% of the harvest was assumed to come from final fellings and 33% was assumed to come from thinnings. In the base run, no forest area expansion was incorporated, so afforestation was assumed to be zero.
- In the 'increased demand scenario' (**ID**), a continuing increase in the demand for biomass and wood products was assumed. The total required harvest was increased over the simulation period of 50 years with 0.1 mln m^3 per year to 10.913 mln m^3 in 2056. Like in the base run scenario, 67% of the fellings were assumed to come from final fellings and 33% from thinnings. In this scenario, the total forest area remained unchanged, so afforestation was assumed to be zero.
- In the 'afforestation scenario' (**AS**), it was assumed that due to afforestation the forest area would yearly expand at a rate of 15 000 ha per year to a total area of 2.609 mln ha in 2056. Of this afforestation, 10 000 ha per year was assumed to take place in all regions of Hungary and 5000 ha per year was situated in the three regions of the Tisza river basin. The 10 000 ha per year were distributed over the regions, proportionally to their surface area (Table 5.5). Further, the species distribution was kept constant, so within each region the areas were distributed over the species accordingly to their present cover. Of the 5000 ha of extra afforestation in the Tisza regions, the largest share of 3000 ha was assigned to the region 'Northern Great Plain' since a main part of Tisza runs through this region. The remaining 2000 ha were assigned to the regions Northern Hungary and Southern Great Plain. The extra afforestation in the three Tisza regions consisted of tree species adapted to conditions in floodplain forest: species of the groups 'Populus and Salix', 'Quercus robur' and 'other hardwood broadleaves' (Table 5.5). The harvest level in the afforestation scenario was kept at the same constant level of the year 2006 as for the base run scenario.

Table 5.5: The level of afforestation in the different regions of Hungary under the afforestation scenario.

	Continuation of historical afforestation level in total Hungary			Extra afforestation in Tisza floodplain	
	Proportion of surface area of Hungary	Area (ha)	Species	Area (ha)	Species
Hungary	1	10000		5000	
Central Hungary	0.07	743.6	Distribution of species proportionally to their areas already present		
Central Transdanubia	0.12	1207.6			
Western Transdanubia	0.12	1204.6			
Southern Transdanubia	0.15	1522.7			
Northern Hungary	0.14	1443.1		1500	'Populus and Salix', 'Quercus robur' and 'Other hardwood broadleaves' at a ratio of 3: 1:1
Northern Great Plain	0.19	1907.5		3000	
Southern Great Plain	0.20	1970.9		500	

5.6.3 Results

Base run scenario, total Hungary

For the base run scenario, it was possible to harvest the requested 5.913 mln m^3 of wood from the forest during the whole simulation period (Figure 5.13). The applied demand level of 5.913 mln m^3 per year resulted in an average removal of 3.2m^3 of wood per year. The average amount of wood which was felled in the forest was higher, 4 m^3 per hectare per year, since we assumed that 20% of the felled wood would be topwood left in the forest after the fellings. During the whole simulation period the increment was much higher than this felling level. The simulated increment for the base run scenario at the start of the simulation was 6.8m^3 per ha per year in 2011, and during the simulation period of 50 years this increment decreased to 5.5 m^3 per ha per year in 2056 (Figure 5.14). Due to the increment level being higher than the felling level, forests had the possibility to age (Figure 5.15). Another result of the increment being higher than the felling level was that the average growing stock per hectare and the biomass per hectare both increased strongly (Figure 5.16 and Figure 5.17). During the simulation period, in total 67 million tonnes extra carbon were stored in the biomass and soil of the forest resource compared to the level of 2006. Most of this carbon was stored in the biomass, since the average amount of carbon per hectare in the soil hardly changed (Figure 5.17).

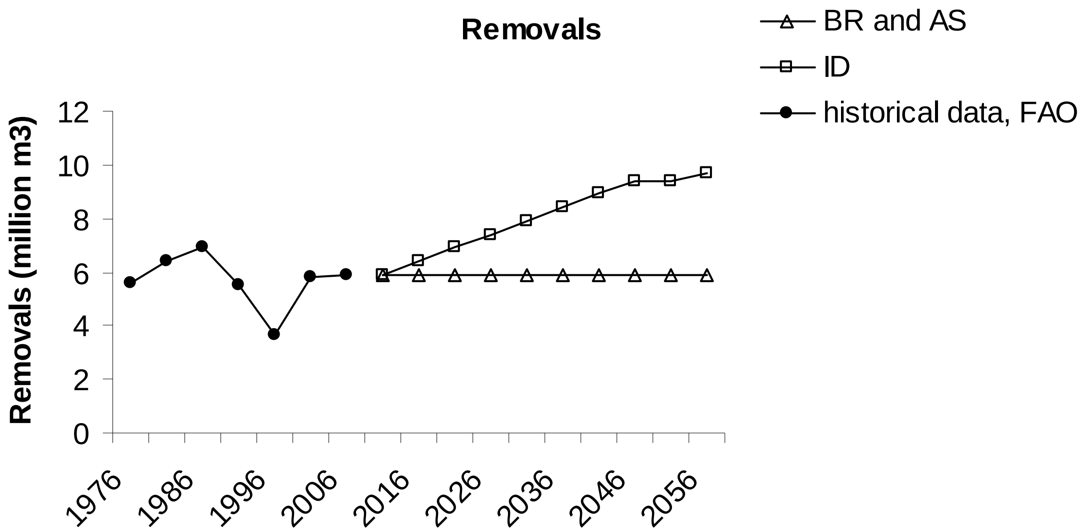

Figure 5.13: The development of the quantity of wood removed from the forests in Hungary: historical data and projections for the base run scenario (BR), the afforestation scenario (AS) and for the increased demand scenario (ID).

Afforestation scenario, total Hungary

Under the afforestation scenario, the same amount of wood was removed from the forest as under the base run scenario (Figure 5.13). And, like under the base run scenario, the increment under the afforestation scenario also showed a relatively strong decrease (Figure 5.14), from 6.7 m^3 in 2011 to 5.8 m^3 per ha per year in 2056. Also under this scenario, the average quantity of wood removed by thinnings and final fellings per hectare was much lower than the average increment, resulting in an increasing area of old forest over the simulation period (Figure 5.15). But, due to the afforestation, the area of young forest increased too (Figure 5.15). Over the simulation period, more carbon was stored under this scenario than under the base run scenario. In total 129 million tonnes extra carbon were stored in the biomass and soil of the forest resource compared to the level of 2006. Due to the afforestation, the average levels of the growing stock and the biomass per hectare increased more slowly than under the base run scenario (Figure 5.16 and Figure 5.17). The expansion of the forest area, with young forests having a low carbon stock in the soil, resulted in a decrease of the average amounts of carbon per hectare in the soil over the simulation period (Figure 5.17).

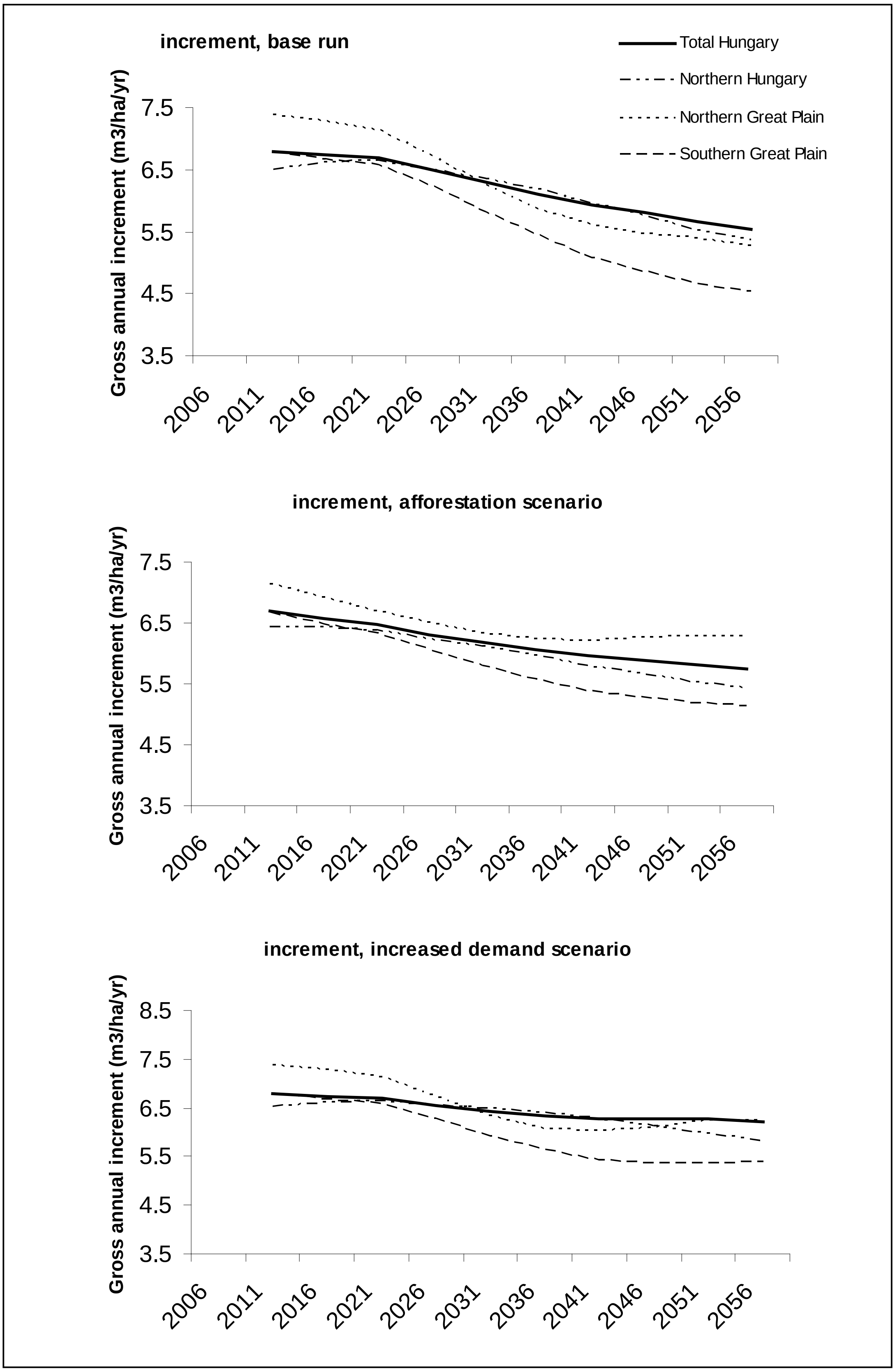

Figure 5.14: The development of the increment for Hungary and for three Tisza Regions.

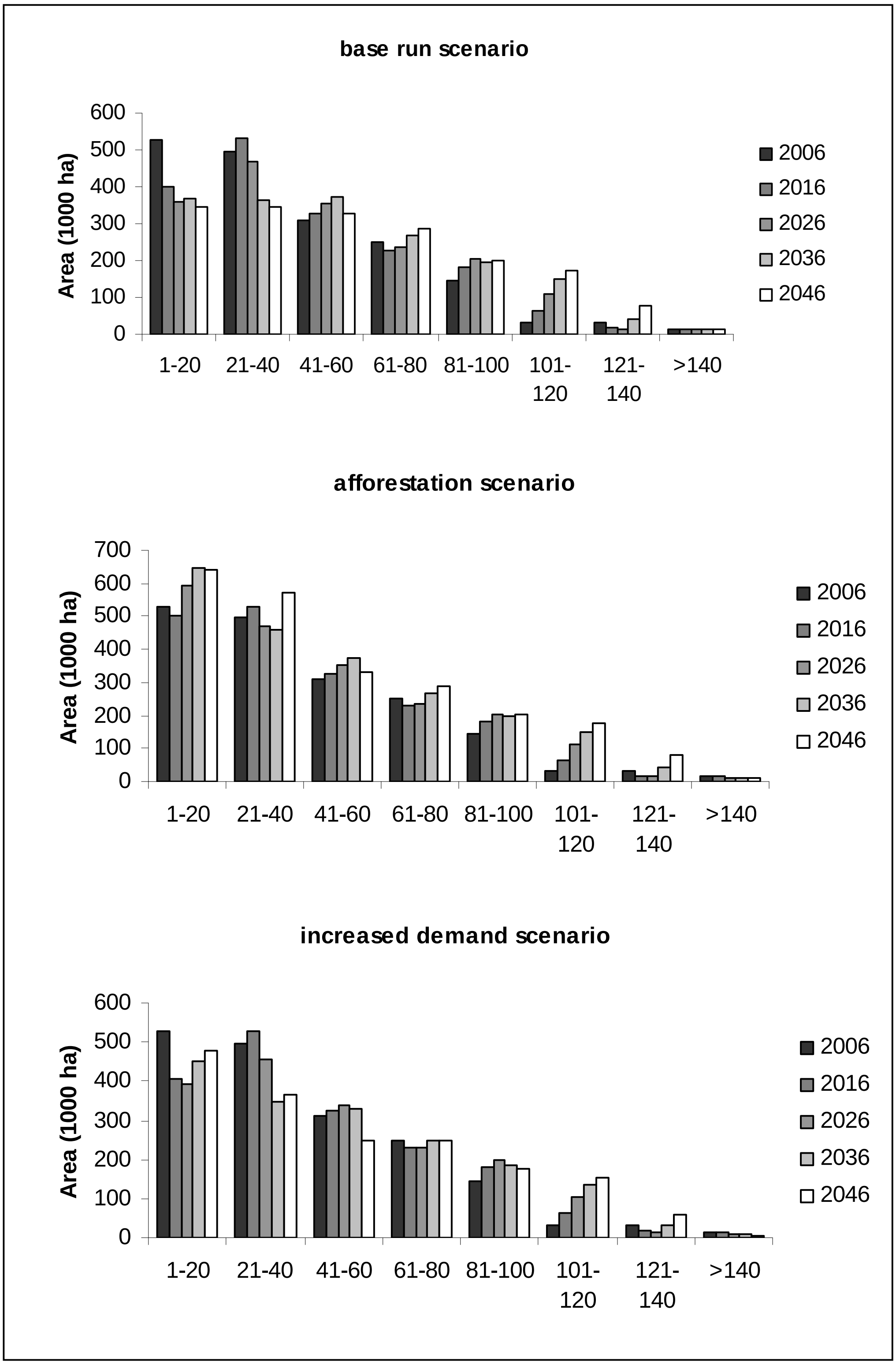

Figure 5.15: The development of the age-class distribution of the Hungarian forest resource for three scenarios.

Increased demand scenario, total Hungary

Under the increased demand scenario, the demand of wood was increased with 0.1 million m^3 per year. At the end of the simulation period, from 2046 on, the model wasn't able to harvest all the requested wood (Figure 5.13) while not all the required thinnings could be found. The model was still able to harvest the requested amount of final fellings. Over the simulation period the quantity of wood removed by thinnings and fellings increased from 5.9 to 9.7 million m^3 per year (Figure 5.13) and at the end of the simulation period on average 5.2 m3 per hectare was removed from the forest and 6.5 m^3 per hectare was being felled. During the simulation the increment slightly decreased (Figure 5.14) to an average of 6.2 m^3 per hectare per year, so at the end of the simulation period the average amount of wood felled in the forest was higher than the average increment. Both the growing stock and the carbon stock in the biomass started to decrease (Figure 5.16 and Figure 5.17). Despite the high harvest level, the proportion old forest still increased, although not as strongly as under the other two scenarios (Figure 5.15).

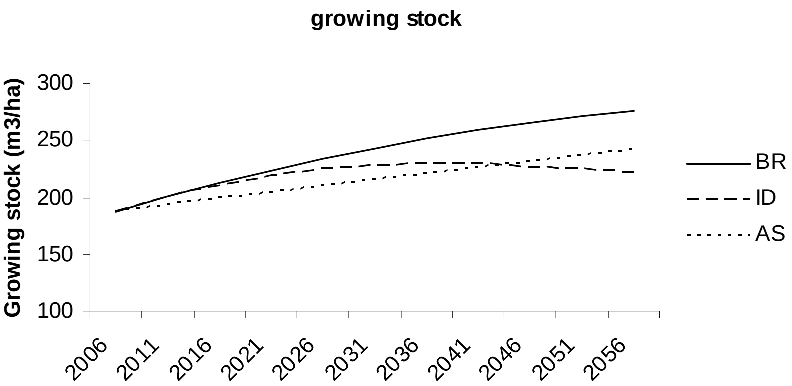

Figure 5.16: The development of the growing stock for Hungary, for the base run scenario (BR), the increased demand scenario (ID) and the afforestation scenario (AS).

Tisza regions, increment

At the start of the simulation, the level of the increment was higher in the region Northern Great Plain than in the other two regions representing the Tisza River Basin (Figure 5.14). Also the development of the increment differed between the three regions (Figure 5.14). For all scenarios, the development of the increment of Northern Hungary was similar to the development of the increment of total Hungary, and for all scenarios the increment of the region Southern Great Plain showed a relatively strong decrease over the simulation period. Also the increment of the region Northern Great Plain showed a relatively strong decrease over the simulation period for the base run scenario and for the increased demand scenario. Under the afforestation scenario, the increment of the region Northern Great Plain started to increase at the end of the simulation period (Figure 5.14)

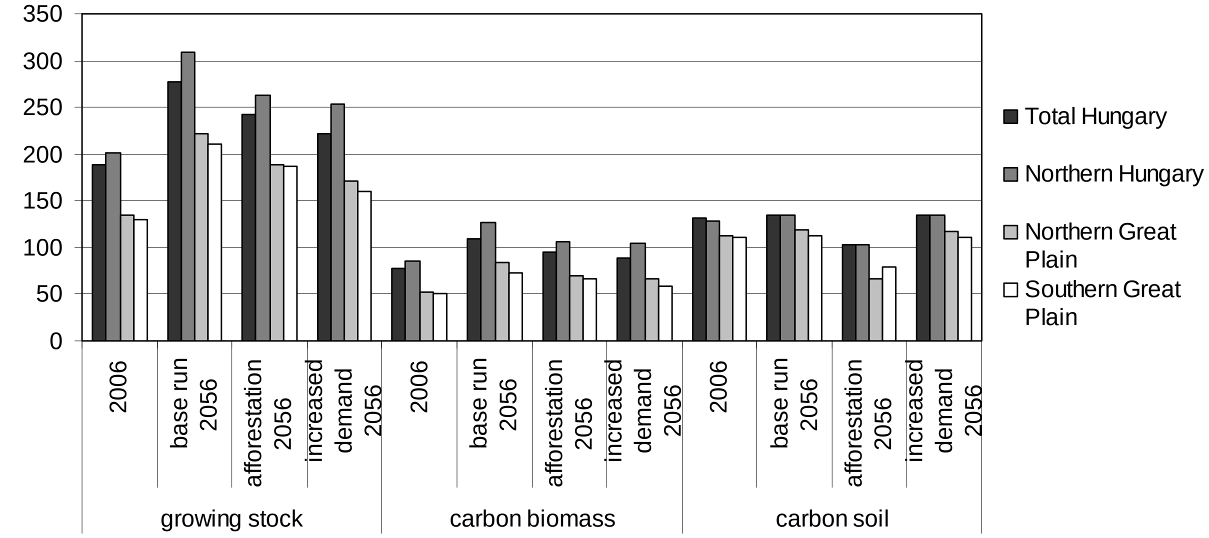

Figure 5.17: The average growing stock (m^3 / ha), average carbon stock in the biomass (Mg C/ha) and average carbon stock in the soil (Mg C/ha) at the start of the simulation in 2006 and at the end of the simulation in 2056 for different scenarios and different areas.

Tisza regions, growing stock and carbon pools

At the start of the simulation, the growing stocks in the regions Northern and Southern Great Plain were much lower than in the region Northern Hungary (Figure 5.17). Over the simulation period, the growing stocks and the carbon stocks in the biomass and soil of the three regions followed the same trends as the stocks of total Hungary, except for the base run scenario. Under the base run scenario, the average growing stock and the carbon stock in the biomass of the two great Plain regions levelled off, while the stocks of total Hungary and of the region Northern Hungary continued to increase (Figure 5.18). Under the afforestation scenario, the growing stocks and the carbon pools of the biomass of the three regions continued to rise, while due to the afforestation the average carbon stocks of the soil decreased, like the stocks for total Hungary (Figure 5.17). Under the increased demand scenario, the growing stocks and the carbon pools of the biomass and soil of the three regions levelled off or slightly decreased at the end of the simulation period, following the same trend as the forest resource of total Hungary (data not shown).

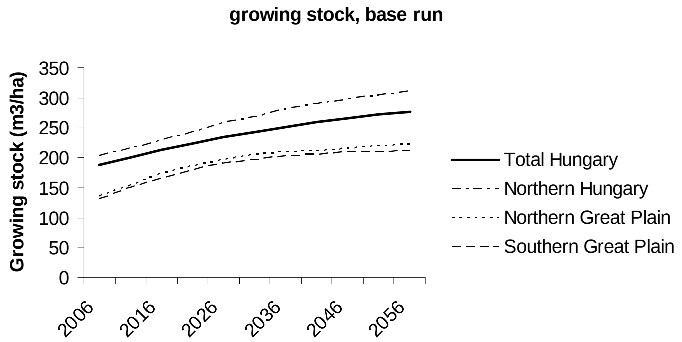

Figure 5.18: The development of the growing stock for the base run scenario for total Hungary and for the three 'Tisza Regions'.

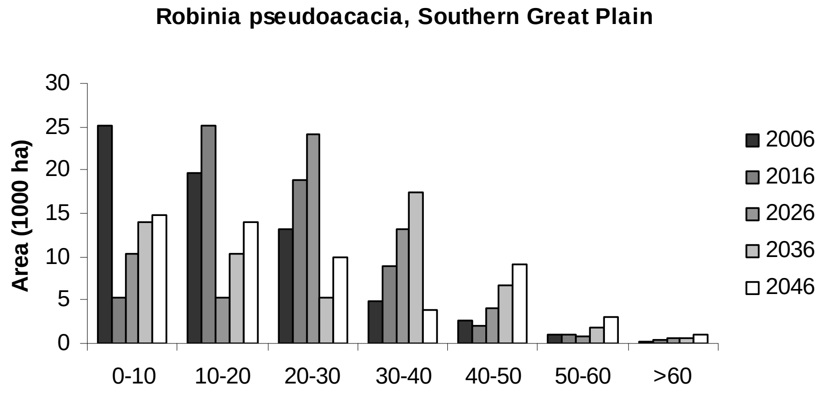

Figure 5.19: The development of the age-class distribution of the species Robinia speudoacaia, for the region Southern Great Plain, under the increased demand scenario

Table 5.6: The average area and growing stock per species for the three regions representing the Tisza River Basin for the year 2006.

	Tree species distribution				Average growing stock (m³/ha)		
	Total Hungary	Northern Hungary	Northern Great Plain	Southern Great Plain	Northern Hungary	Northern Great Plain	Southern Great Plain
Total area (1000 ha)	1859.3	391.6	202.9	218.5			
Species	Forest area (as percentage of total area)						
Q.robur	8.8	2.7	18.7	6.5	153.6	168.7	179.6
Q.petraea	9.8	27.2	0.0	0.0	239.2	175.8	294.8
Other hardwood broadleaves	7.1	4.4	6.5	5.8	174.9	181.1	171.8
Q.cerris	11.7	19.6	0.4	0.6	157.3	132.1	120.9
F.sylvatica	5.8	11.6	0.0	0.0	331.3	9	18
C.betulus	5.0	8.1	0.3	0.0	156.5	169.9	126.5
R.pseudoacacia	23.2	14.2	40.6	30.6	107.9	99.9	80.1
Populus and Salix	11.5	3.7	27.4	30.9	160.7	127.5	132.5
Other softwood broadleaves	5.1	1.1	0.7	0.3	197.6	157.3	184
P.sylvestris	7.0	4.0	5.0	7.7	266.1	236.7	220.3
P.nigra	3.6	1.3	0.4	16.9	257.6	278	146
Other conifers	1.4	2.1	0.1	0.7	254.4	232.6	42.2
Total	100.0	100.0	100.0	100.0	201.6	133.9	130.3

5.6.4 Discussion

Increment

The increment at the start of the simulation was 6.8 m^3 per hectare per year which is comparable to the increment level of 6.7m^3 per ha per yr mentioned by (Mészáros et al., 2005) for the year 2003 and slightly higher than the 6.5m^3 per hectare per year reported by (Schelhaas et al., 2004) for the year 2000. Research suggests that the increment level in Hungary has increased last years due to climate change (Somogyi, 2008). This effect will probably only be temporarily since in future drier summers are expected and water shortage will probably soon start to limit tree growth (Somogyi, 2008).

During the simulation period of 50 years, the increment decreased to 5.5 m^3 per ha per yr (Figure 5.14). A similar result was found in the study by Schelhaas et al. (2004). They calculated a decrease from 6.5 m^3 in 2000 to 5.1 m^3 in 2050 for their business as usual scenario. The relatively strong decrease in increment for the base run and afforestation scenarios (Figure 5.14) can be explained by changes in the age class distribution of the forests. Under both scenarios, the area of old forest increased (Figure 5.15). Since old forests have in general lower increment levels than younger forests, these changes in age class distribution resulted in lower increment levels. Under the increased demand scenario, the area of old forest increased too (Figure 5.15). However, the area of forests older than 60 years at the end of the simulation period was 110 000 hectares smaller than under the other two scenarios, resulting in a slight decrease of the increment only (Figure 5.14).

The level of the increment and the development of the increment differed between the three regions which represent the Tisza river basin (Figure 5.14), which can largely be explained by differences in tree species distribution. In the regions Northern Great Plain and Southern Great Plain especially the species Robinia pseudoacacia (Black locust) and Populus spp and Salix spp (poplar and willow) were common at the start of the simulation (Table 5.6). The average growing stock of these species is relatively low, explaining the low average growing stock in both regions (Table 5.6). At the start of the simulation, the forests of these species were still young, resulting in the relatively high increment of the region Northern Great Plain, since especially when young these species have high growth rates. Although the region Southern Great Plain had relatively large areas of young forests of these species too, the increment in this region was about 0.6 m^3 per hectare lower than in the region Northern Great Plain (Figure 5.14). This difference was mainly due to differences in initial growing stocks. In the EFISCEN model, growth is calculated by applying a growth function on a growing stock. At the start of the simulation, both regions had relatively large areas of young Robinia forests, but the average growing stock of Robinia forest was higher in the region Northern Great Plain than in the region Southern Great Plain (Table 5.6).

The relatively strong decrease in increment in the regions Northern Great Plain and Southern Great Plain under the base run scenario (Figure 5.14) can be explained by tree species distribution too. Especially the species Robinia pseudoacaia and Populus and Salix showed a relatively strong decrease in increment over the simulation period, due to these forests getting older. Older stands of Robinia and Populus and Salix forests have considerably lower increments than stands of 10-30 years old. As a result of the low increments in these regions at the end of the simulation period, the average increment started to approach the average felling per hectare. This resulted in the levelling off of the average growing stocks and the aboveground biomass in these regions.

Changes in age-class distribution of Robinia pseudoacacia and Populus and Salix stands were also the reason for the relatively strong decrease of increment for these two regions under the increased demand scenario (Figure 5.14). Over the simulation period, the areas of 10-30 year old forest of these species decreased under this scenario while areas with old or very young forest of these species increased (Figure 5.19). The small decrease in increment under the afforestation scenario for the region Northern Great Plain can be explained by the establishment of new forests of particularly Populus and Salix in this region. The relatively high growth rate of these young stands caused the increment to stay higher.

Mitigation potential

The results from the base run scenario and from the afforestation scenario show that presently the average felling level is considerably lower than the increment, leading to a building up of the growing stock (Figure 5.16). This increasing growing stock might contribute to the mitigation of climate change, since the forests take up the greenhouse gas carbon dioxide and store carbon. But how significant is this storage? The afforestation scenario led to an increased storage of about 62 million tonnes C over the simulation period compared to the base run scenario. This 62 million tonnes is similar to an average storage of about 1.24 million ton C per year, equivalent to 4.5 million tonnes carbon dioxide per year or about 6% of the total annual greenhouse gas emission of Hungary (2009).

The biomass production of the forest resource might also be used to mitigate climate change in another way; by the production of renewable energy. The results of the increased demand scenario show that the harvest level might be increased considerably without the growing stock to decrease. The results indicate that at a harvest level of about 8.4 million m^3, the level which the increased demand scenario reached in 2036 (Figure 5.13), increment and felling are equally high (Figure 5.16). This means that an extra 2.5 million m^3 wood might be extracted from the forest annually without the growing stock to go down. If also topwood would be extracted, and if we assume a conversion factor of 0.51 g dry mass/cm^3 fresh wood (Zanne et al., 2009), an extra 3.1 million m^3 wood, equivalent to 1.6 million tonnes dry mass might be extracted from the forests. If the extra wood extracted from the forest would be burned for energy production, as a renewable source of energy to mitigate climate change, this might produce about 27 PJ per year, assuming the production of 17.1 PJ/ million ton dry mass (Spijker et al., 2007). This 27 PJ would mean about 2.5% of the total annual energy consumption of 1100 PJ of Hungary (Mészáros et al., 2005).

Conclusion

In this study, two alternative scenarios to mitigate climate change by the forest sector of Hungary were assessed. An afforestation scenario, with an afforestation effort concentrated in the Tisza river basin area and a level of afforestation which was about 50% higher than the historical level of last decades, and a scenario of increased demand for wood. The results from the simulations indicate that afforestation, increased harvesting or a combination of these measures can significantly contribute to the mitigation of climate change.

5.6.5 References

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5.7 Flood risk maps

Nicola Lugeri (JRC), Edina Balogh (BUTE-DSEE)

5.7.1 Introduction

An application of the flood risk assessment methodology developed at the JRC and used throughout the ADAM project activities of Work Package A2.1, has been applied in the Tisza river basin. The objective of this section is to introduce the results and compare them to an existing study -with higher spatial detail- from the Budapest University of Technology and Economics (Koncsos and Balogh, 2007).

5.7.2 Method

Based on the "Risk Triangle" paradigm (Crichton, 1990), the methodology relies on a relatively simple and low computing power demanding GIS overlay mapping procedure. Raster maps describing the three entries of the definition of risk: Hazard, Exposure and Vulnerability were compiled. Figure 5.20 illustrates the implementation of the flood risk assessment approach that has been described in detail in ADAM project reports (Lugeri, 2007)

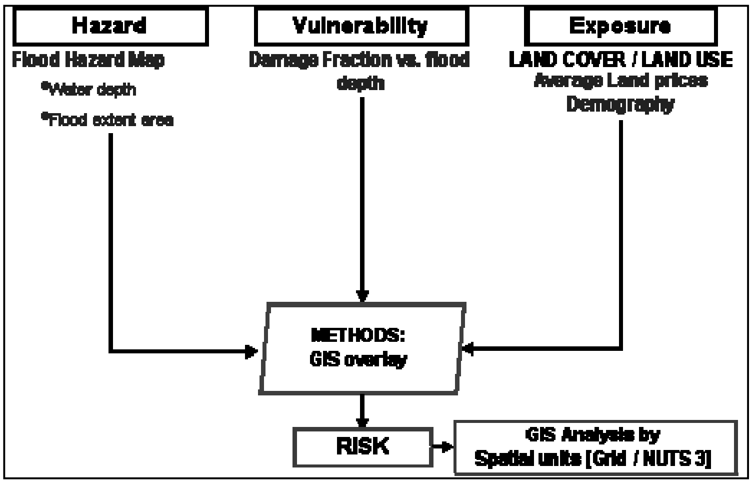


Figure 5.20: Schema of the GIS Flood Risk assessment procedure

For the Tisza valley case study, a hazard map was used that was more detailed than that of the European-wide study in ADAM WP 2.1. This map had been produced by JRC and was used in WP A2.1 as a calibration input for a coarser hazard map. The map used for the Tisza case study relies on the LISFLOOD hydrologic model (De Roo 1998), driven by meteorological data on 12km*12km grids, running on the pan-European river network at 1km resolution. The computed river discharge (in relation to given probability of occurrence) is first transformed to water levels in the river and next to flood depths, by means of the SRTM DEM (100m resolution) assuming no explicit defence structures. A flood extent/water stage map was produced for each return period chosen in the assessment (namely, 20, 50, 100, 250 and 500 years return period). Exposure and Vulnerability were modelled by territorial databases based on the Corine Land Cover nomenclature and mapping (EEA 2000). In Figure 5.21 is shown the flood hazard map for the 100-year return period in the Tisza basin.

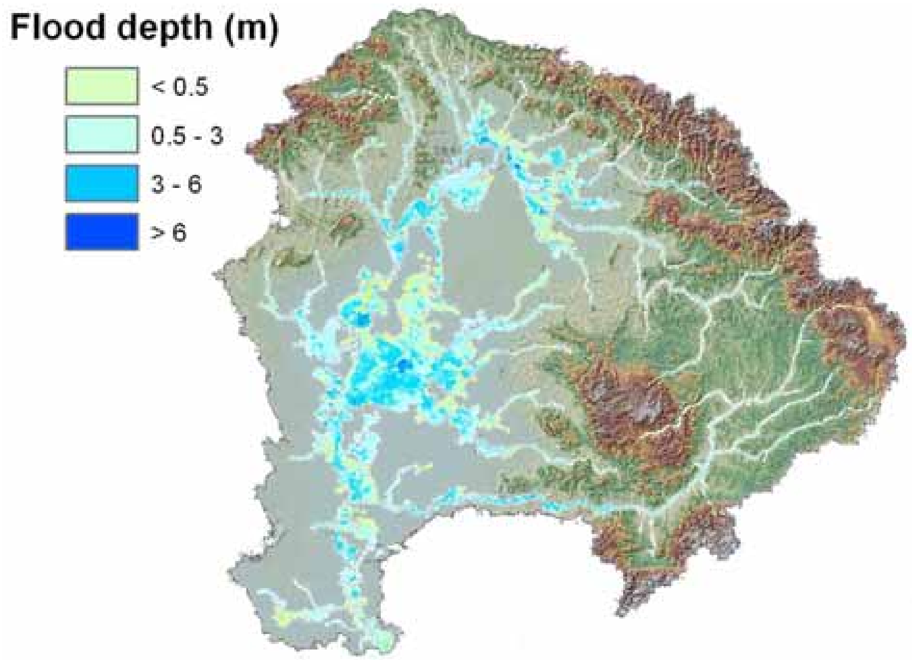


Figure 5.21: Extent and flood depth classes for the 100-year flood in the Tisza basin

Figure 5.22 shows the hazard map overlaid on the Corine Land Cover map, in the Upper Tisza at the Hungary-Ukraine border. The Corine Land Cover map is not available for Ukraine and Serbia, so that the assessment was performed for Hungary, Rumania and Slovakia.

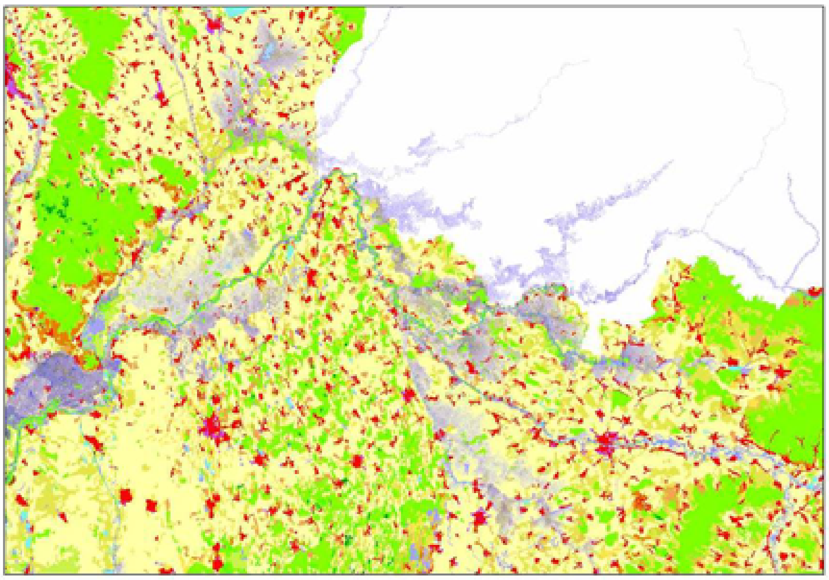
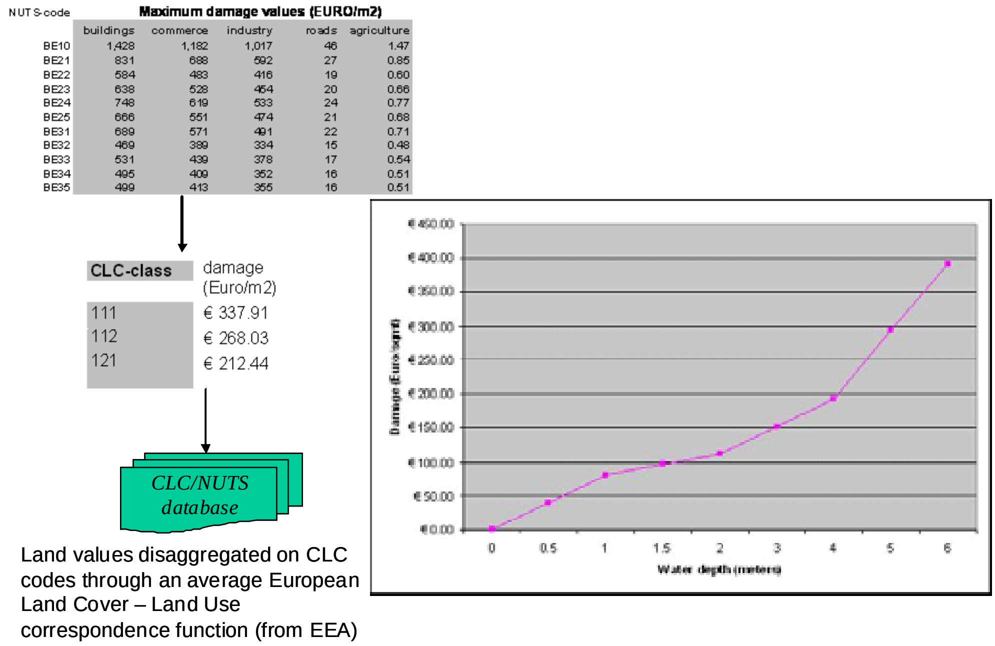


Figure 5.22: Flood Hazard map overlaid on Corine Land Cover map



NUTS-code	buildings	commerce	industry	roads	agriculture
	Maximum damage values (EURO/m2)				
BE10	1,428	1,182	1,017	46	1.47
BE21	831	688	592	27	0.85
BE22	584	483	416	19	0.60
BE23	638	528	464	20	0.66
BE24	748	619	533	24	0.77
BE25	666	551	474	21	0.68
BE31	689	571	491	22	0.71
BE32	469	389	334	15	0.48
BE33	531	439	378	17	0.54
BE34	495	409	352	16	0.51
BE35	499	413	355	16	0.51

Figure 5.23: Implementation of Exposure and Vulnerability information in the GIS method.

Figure 5.23 illustrates how land cover information is converted into monetary values, using a dedicated study commissioned by JRC (HKV, 2007). Results correspond to the Exposure (value per m^2) and Vulnerability (stage-damage function) aspect in the "Risk Triangle" method (Figure 5.20). The resulting risk maps, are raster maps with territorial resolution of 1 hectare, related to a particular flood return period. This spatial information is converted to Annual Average Damage by summing grid-cell damages over administrative (provinces or municipalities) or physical (basins) boundaries.

5.7.3 Results

Figure 5.24 to Figure 5.26 show results of the method. Only Hungary, Rumania and Slovakia are covered because of lack of CORINE Land Cover data for other countries in the Tisza basin.

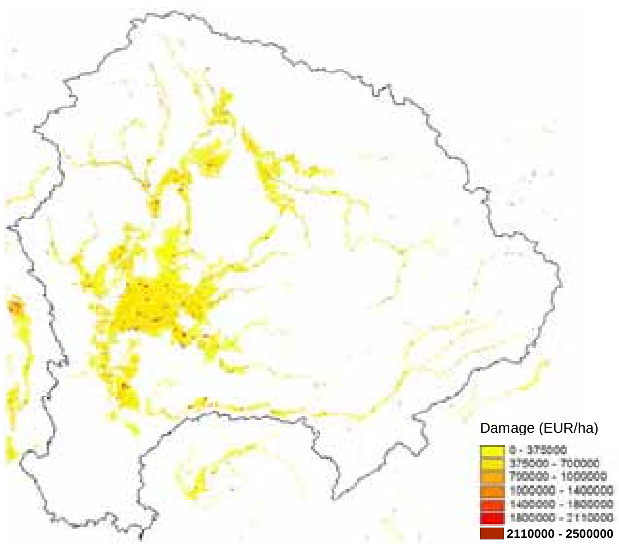


Figure 5.24: Map of the assessed monetary damage for the 100-year flood.

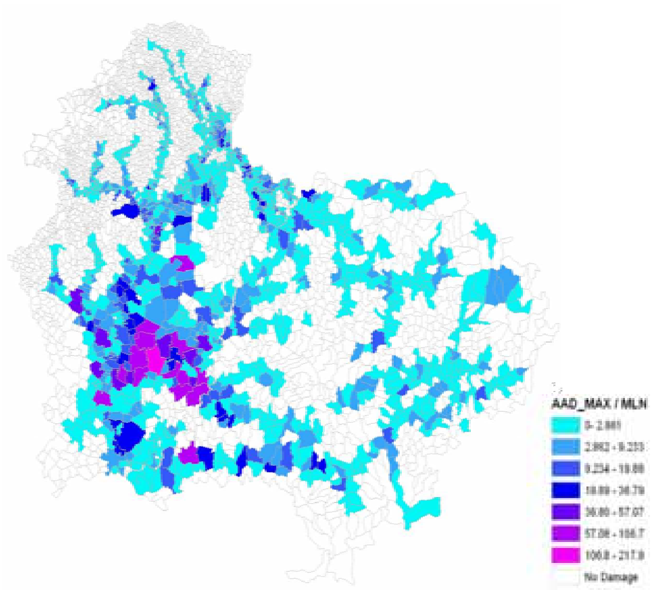


Figure 5.25: Average annual damages aggregated by administrative boundaries (here, municipalities in Hungary, Rumania and Slovakia belonging to the Tisza basin)

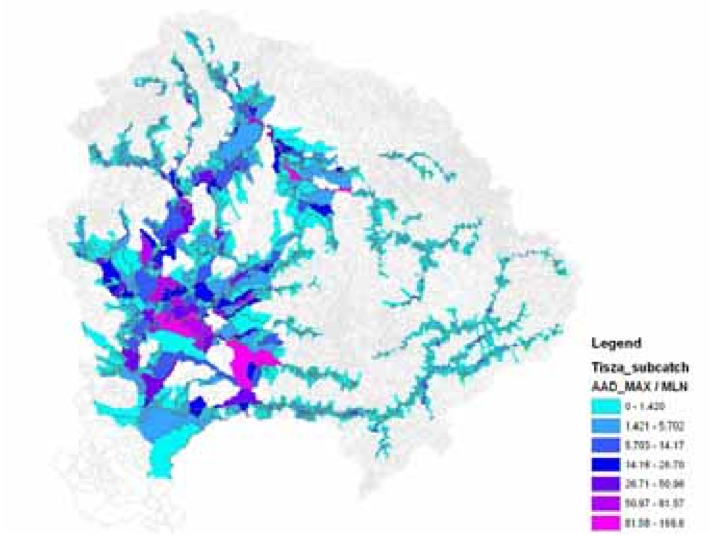


Figure 5.26: As Figure 5.25, but aggregated over the smallest sub-basins of the Tisza basin.

Different scenarios can be assessed by the model. For example climate change scenarios can be used to drive the hydrologic model and assess future flooding hazards. Adaptation measures can be introduced to affect exposure and vulnerability. An example of this was the request to assess the impacts of land use change and the notion that in the agricultural sector, shallow flooding can be an asset rather than a cost. To assess this the damage functions were modified. Technically this means that the model returns negative monetary losses -representing a gain- as shown in Figure 5.27. In this case, flood depths below 40cm results in 'negative Vulnerability', which means a monetary gain.

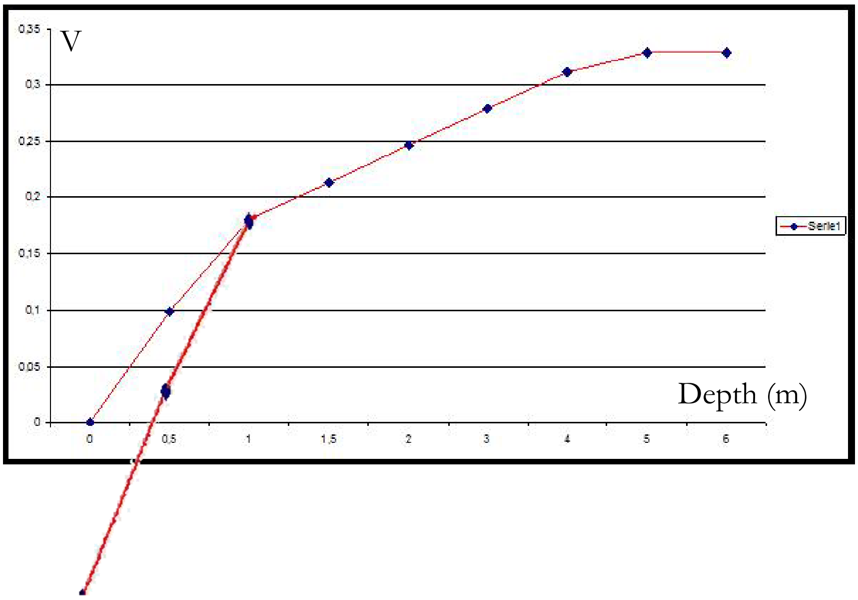


Figure 5.27: Modified damage curve for CORINE Land Cover class 211 (Arable Land) for Hungary.

Figure 5.28 - Figure 5.30 correspond to Figure 5.24 - Figure 5.26 after the insertion of the modified Vulnerability, illustrated in Figure 5.27.

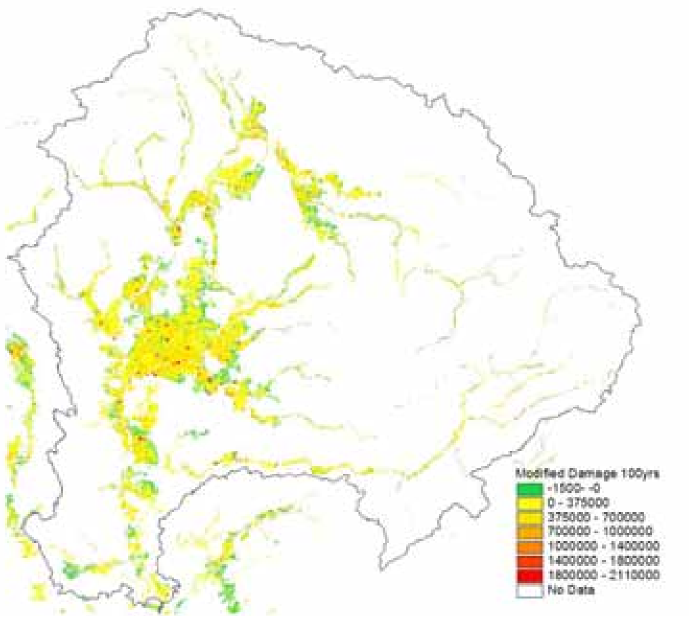


Figure 5.28: Map of the assessed monetary damage for the 100-years flood*, with the modified Vulnerability*

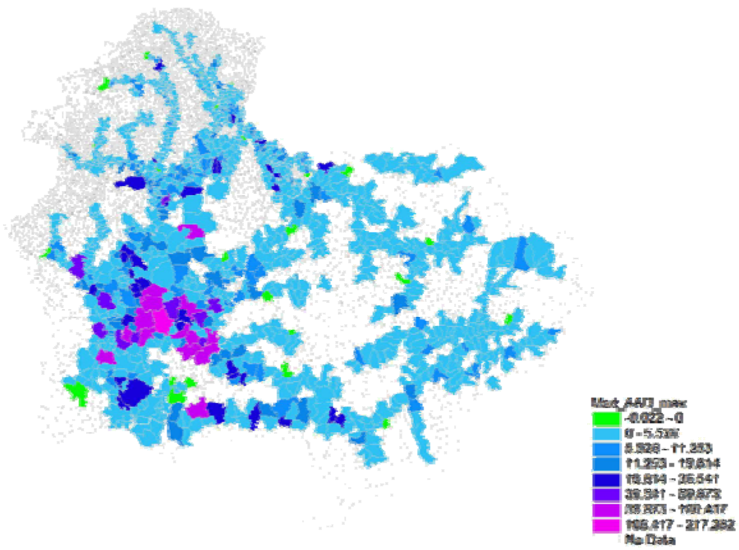


Figure 5.29: Spatial aggregation of the resulting Annual Average Damage over administrative boundaries, with the modified Vulnerability

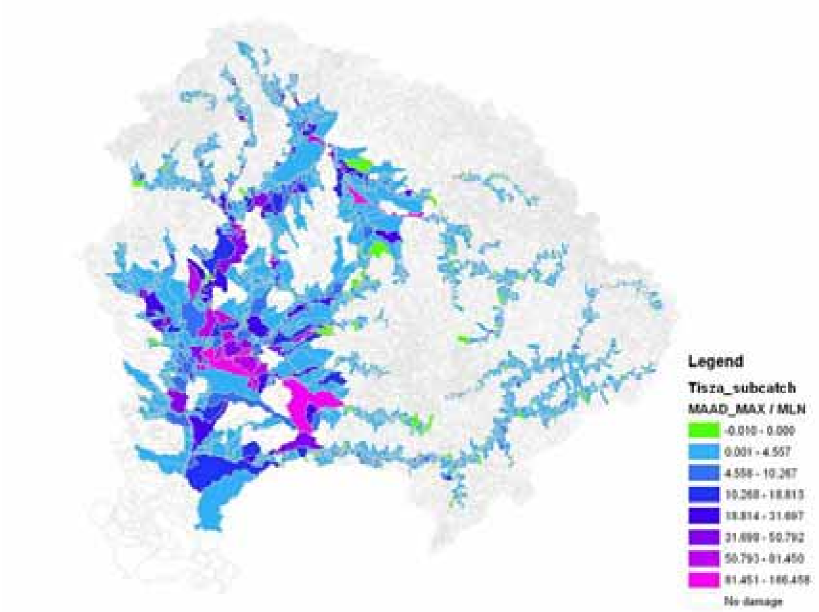


Figure 5.30: Same as Figure 5.26, with the modified Vulnerability

Results of the JRC modelling work were compared to a study that was carried out by the Hungarian BUTE DSEE Institute for the Hungarian part of the Tisza river (Koncsos and Balogh, 2007). Although we were aware of the large differences between the two methods, a comparison exercise was carried out, encouraged by the interest expressed by various stakeholders during workshops.

The Hungarian study combines results from a 1- and a 2-dimensional hydrological model. Next to more detailed meteorological inputs, it uses a four times finer digital elevation map than the JRC study (25 m and 100 m respectively). The approach is based on Bayes decision theory, with a Monte Carlo catastrophe simulation (over a 100 year time period). The model includes water defence infrastructure and the probability of its geotechnical failure, in addition to "simple" overtopping. The only thing that the Hungarian and the JRC method have in common is the use of Corine Land Cover data.

Figure 5.31 shows that the comparison of the flood extent is quite poor, but this was to be expected as a result of the different scales and the absence of flood defence infrastructure in the JRC method. The BUTE study only returns extents from localized events (overtopping or geotechnical failures) along the Tisza main stream, while the regional model from JRC does not account for artificial defences and considers the whole Tisza basin river network.

In addition, damage computed by BUTE represent a summarized value over a 100 year Monte Carlo simulation, which is not the same as that attributed to a 100-year return period as it does not relate to only one flood, but to all floods which occur during the examined 100 years.

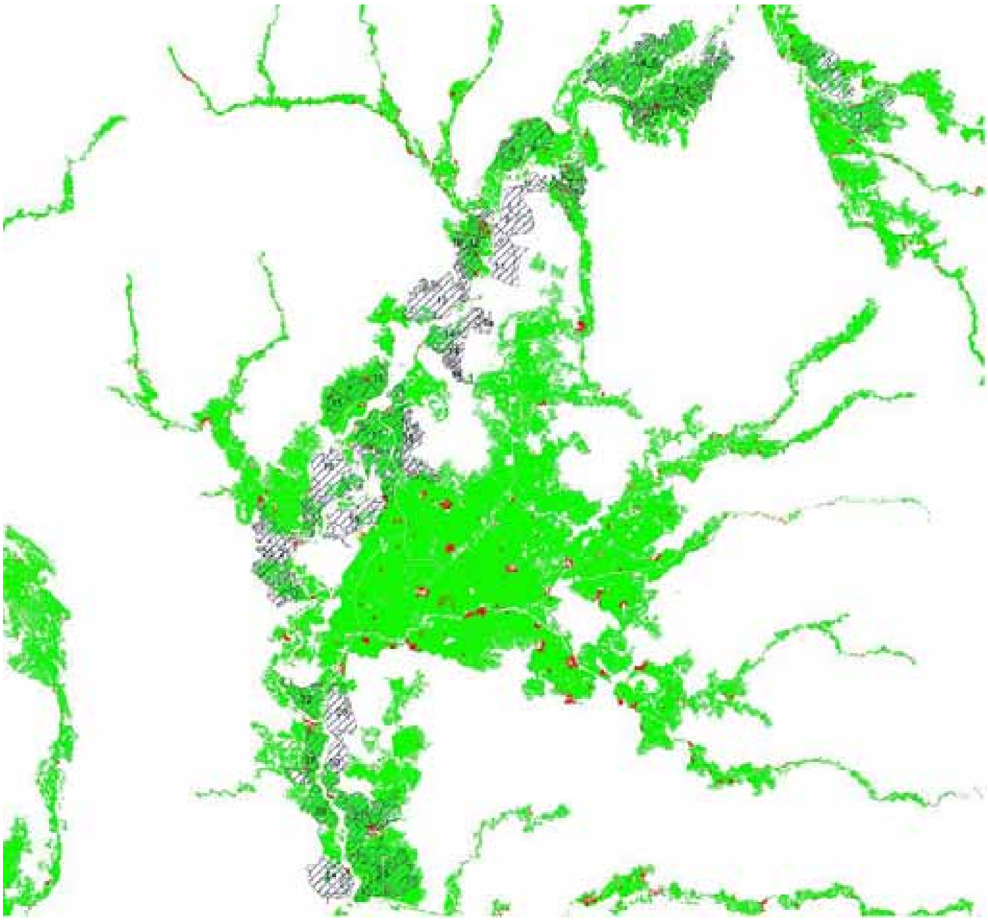


Figure 5.31: Comparison of flood extent from the BUTE DSEE study (dashed) and from the JRC Hazard map (fill colour).

Nevertheless, the total damages calculated by BUTE DSEE agree relatively well with the total damages assessed by JRC; with those of BUTE DSEE 13% higher. Yet it is difficult to prove that this is not a simple coincidence. Especially when we consider the poor correspondence in the flood extents and flood depths.

The damages were also compared on a NUTS3 level (CEC 2003), showing reasonable agreement in half of the provinces involved. Another check was to use the JRC damage functions (based on CLC classes) on top of the flood maps by BUTE DSEE and compare this to the published values. The idea was to see if the estimations of the damage functions used at JRC are similar to those used in the Hungarian study. Half of the BUTE DSEE flood zones show a variation of less than 40% (either + or -), while some areas show much larger differences. The main reason for this is that although the Corine Land Cover has been used to describe land use in both studies, a statistical database of local distribution of housing has been overlaid in the BUTE DSEE study. This layer includes information that is not present in JRC damage functions, like statistical data on housing types.

5.7.4 Conclusions and outlook

Trade-offs between the detail of the model and the spatial extent have driven the choice of the modelling techniques (especially in terms of data availability, model design and calibration, and computing time and power). To better understand the consequences of this choice for the modelling of flood risks, it is an important task for the future to align the two methods and facilitate the comparison. At the same time, an effective communication has to be established between stakeholders and modellers to identify the relevant questions and, within the inevitable uncertainties, find the most reliable answers.

5.7.5 References

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HKV Consultants (2007) Flood damage functions for EU member states. Final Report for Contract n. 382441 – F1SC for the European Commission, Joint Research Centre (not for disclosure)

5.8 Earth system governance & actors in adapting land use and water management

Werners, S. E., Z. Flachner, P. Matczak, M. Falaleeva and R. Leemans (2009) Exploring earth system governance: a case study of floodplain management along the Tisza River in Hungary. Global Environmental Change (accepted).

Summary: This paper discusses a recently proposed conceptualisation of 'earth system governance' by applying it to floodplain management in the Hungarian Tisza river basin. By doing so it aims to add to our understanding of governance systems that facilitate adaptation to a changing world. The conceptualisation of earth system governance consists of three elements: problem structure, principles and research challenges. This paper evaluates these three elements using results from actor interviews and policy reviews. The paper shows that a regional example of natural resources management can offer a valid case for earth system governance research. The proposed conceptualisation of earth system governance explains well the main problems, barriers and opportunities for adapting floodplain governance to climate change in the Tisza region. Current barriers can be attributed to a lack of the key governance principles credibility, stability, inclusiveness and adaptiveness. The options that actors identify to facilitate the adaptation of floodplain management to climate change are covered by the proposed research challenges. A remaining research challenge for earth system governance is the prioritisation of actions to support an existing governance system and its actors to adapt to climate change.

Werners, S. E., P. Matczak and Z. Flachner (2009) The introduction of floodplain rehabilitation and rural development into the water policy for the Tisza River in Hungary. In Water policy entrepreneurs: A research companion to water transitions around the globe (eds Huitema, D. and S. Meijerink). Edward Elgar Publishing, Camberley, UK - Northampton, USA (in press).

Summary: This paper analyses the transition in the water policy of the Hungarian Tisza River. For 150 years water management was dominated by actors aiming primarily at flood protection and river regulation, serving mostly the interests of large-scale agriculture. In 2001 the opposition started to grow. A new advocacy coalition successfully introduced floodplain rehabilitation and rural development into the water policy. The paper section focuses on the role of policy entrepreneurs and the strategies that they –consciously or unconsciously- used in bringing about policy change. Five strategies are explored: to develop new ideas, to build coalitions & sell ideas, to create and use windows of opportunity, to play multiple venues and to orchestrate and manage networks. For the Tisza case we discuss the importance of each strategy and what individuals are behind it. Our analysis emphasises the importance of recognition of a new policy concept at an abstract level by the responsible civil servants and avocation of the concept by a credible regional coalition. The international and political attention following the 2000 cyanide disaster, the 2001 floods and the 2002 national elections, provided a clear window of opportunity for adoption of the new water policy. The study concludes with a discussion of the difficulties faced when trying to implement a new water policy that runs counter to a region's long-established traditions. Ambiguity about the practical implementation of new concepts and the responsibility of different actors facilitated reaching consensus on a new water policy but seriously hampers implementation in recent years.

5.9 Property rights and adaptation to climate change

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Submitted to Journal Regional Environmental Change

The role of property rights is acknowledged in IPCC reports and other literature dealing with climate change and adaptation. The property rights allocation is considered as one of the determinants of mitigative, and adaptive capacities (Yohe at al. 2007). It appears in the context of social capital, cultural values and institutions. There is little knowledge however, about the mechanisms involving property rights within adaptation processes. The issue of property rights is discussed in the literature on resources economics. Specifically, it is investigated how clarification and allocation of property rights influence the maintenance of natural resources. The literature suggests that, beside legal provision, it is important how property rights regimes are perceived and how they are embedded in the local social and economic life.

The study aims at an in-depth recognition of the role of property rights in adaptation to climate change. It explores the relation between property rights and adaptive capacity building for the case of floodplain management in the Hungarian Tisza river basin. The question is raised whether the property rights structure poses constraints or opportunities for adaptation and what the impact is of the property rights regime on adaptive capacity and on adaptation policy. Construction of the first reservoir for the floodplain management of the plan Tisza river is investigated. The analysis took a multi-scale approach. In terms of time frames, changes of water management regimes in the Tisza River Basin in last 150 years is considered. Changes in the property rights regimes, taking into account the important moments of 1918; 1945; 1962; 1990-3 are also considered. In terms of spatial scales the analysis starts with the focus on local scale (village) but also regional one (province), national one (the national program of floodplain management) and transboundary level of the river basin are treated as frames of the analysis. The study illustrates the crucial role played by property rights in floodplain management in the Hungarian Tisza river basin.

The system of property rights clearly influences both vulnerability and adaptive capacity. Property rights structure also impacts the state's role in the adaptation process. The structure of property rights influences coordination and transaction costs in adaptation: e.g. if there are many small land owners to negotiate with the implementation of certain adaptation requires more time and the costs of negotiating and reaching an agreement increase; in some cases in might be also impossible to reach an agreement within the given adaptation option.

The analysis of the Cigand reservoir construction supports the view that property rights influence the adaptation policy. It is not the absence of property rights which is causing the problem but their unclear character. Dynamic changes of the property rights regime, particularly privatisation, has unintended consequences. The VTT program was set up as a centrally administered program. However, after the stakeholders' protests the program was reorganized and integrated a higher number of non-state actors. The main objective of the program - flood protection and adaptation to climate change, concern non-market goods. According to Stern, an active role of the state is in such situation necessary. Still, property rights pose a serious problem for implementation of measures like landscape management. The socialist experience and distortion of local networks makes self-organization of local communities rather unlikely. At the same time the state's actions do not contribute to local adaptation capacity building. Rather they sustain the sense of helplessness in the communities and open a space for opportunistic behaviour.

5.9.1 References

Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, (2007). Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 811-841.

5.10 New financial approaches for adaptation: a micro-grant scheme

Zsuzsanna Flachner, Péter Kajner (The Living Tisza Alliance)

5.10.1 Introduction

This study aims to identify new financial approaches for adaptation following the concept of micro-credit schemes developed in Bangladesh and India, and thereafter applied in many other countries (Yunus, 2003). It presents a description of the 'Living Tisza Micro-Grant Scheme' along funding results and further steps, highlighting links to the objectives defined in our Tisza scoping document (ADAM, 2007).

5.10.2 Socio–economic relevance of the micro grant scheme in the Tisza river basin

Socio-economic factors were identified that increase human vulnerability in the Tisza river basin and that could be addressed in a micro grant scheme. These factors include

- Nationally the highest unemployment rate (depending on the micro region, the rates are between 12-30%).
- Low education level of the local population, especially among gypsy minorities has an important role in the social degradation process (Ungvári, 2002).
- The main income opportunities are agriculture related (production and processing, trading) with only a small proportion of the local population working in other sectors (municipalities or industry).
- Alternative income opportunities, such as multi-functional farming, where tourism or other activities - honey production, collection of herbs and mushrooms; biomass production- exist, but at present only increase the livelihoods a few families in the region (VÁTI, 2005).
- River normalisation and floodplain drainage have added to the degradation of integrated land and water utilization structures that provided divers livelihood opportunities for the local population (Sendzimir et al, 2008; Bellon, 2004; Andrásfalvy, 1973). In addition the drained floodplain areas started to degraded (e.g. secondary salinization, soil compaction, ecological

diversity loss, degradation of wetland areas), lowering the agricultural production capacity and ecosystem services provided in the Tisza river basin.

These issues were addressed in the formulation of the Tisza biodiversity project, aiming at floodplain revitalization and rural development through integrated floodplain management. The conceptual background (Figure 5.32), as well as the result of work in six pilot area and several scientific projects were evaluated recently and bottlenecks were identified (UNDP-GEF, 2005-2008; www.elotisza.hu, Kajner et al, 2008).

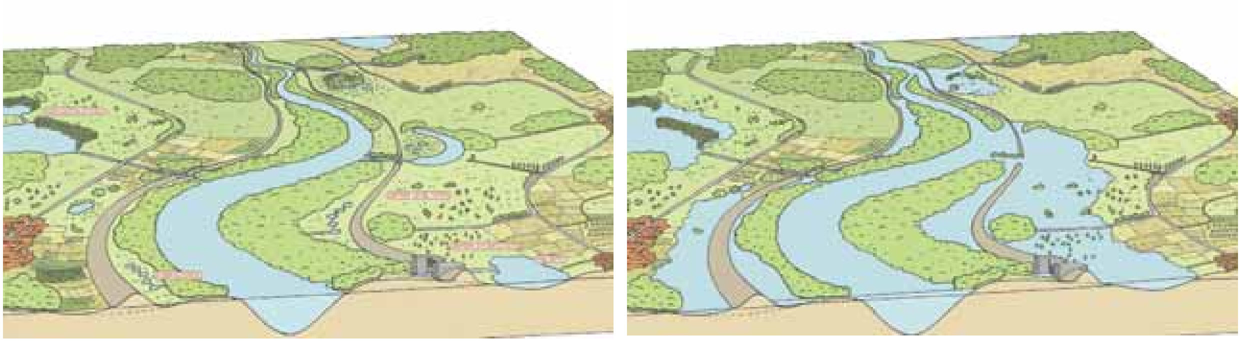


Figure 5.32 The visualized integrated floodplain management in summer and during flooding (courtesy Living Tisza Alliance)

Among the bottlenecks the financing mechanisms has been considered one of the most important. This inspired the creation of a micro-grant scheme for the realization of small-scale local initiatives.

5.10.3 International background of micro-credit schemes

Micro credit is the extension of small loans to those in poverty designed to support establishment of self-sufficient income generation (livelihood provision). The main characteristics of the beneficiaries are no or bad credit history and lack of stabile income, which excludes them from conventional credit schemes. Micro credit is part of a wider range of financial services to vulnerable, poor people. Micro credits were pioneered by the Grameen Bank in Bangladesh. More recently, the UN declared the year 2005 "International year of Microcredit", proving its role in poverty and vulnerability reduction (UNCDF, 2005).

At present several developed countries have joined the initiative and in India the National Bank for Agriculture and Rural Development (NABARD) provides funds to more than 500 local bank units to support so-called '*self-help groups*': small groups of around 20 people, mainly from the lowest social groups. The objective is to save a small amount in a joined fund, that members can borrow for different purposes. If a group proves its capacity in self-financial management, they are eligible to borrow money from the bank to increase their ability to invest in farming or other small scale businesses. The interest rate is 12 to 24 % and depends on the special calculation (Yunus, 2003). The scheme became so popular, that several web based, small scale micro-lending services were introduced over the world (eg. kiva.org; babyloan.org, veecus.com). These services provide opportunities and environmentally sound small business developments both for developing and developed countries poor social groups. Summarising, micro credit schemes aim to facilitate the growth of a micro-finance sector by introducing new modular approaches in project financing. The process supports the flow of financial services to financially vulnerable people, and has multiple effects for the community. These are (Sapovadia, 2006):

1. Building partnerships with private banks, governmental agencies, NGOS and self help groups. The process supports the development of social and corporate responsibility as well as the self organization capacity of local actors (in several cases linked to community trust development and increase cooperation)
2. Funding support – contributing to equity and to lower social segregation, improving livelihood.
3. Capacity building and education – where self help group members learn from each other, from the collaborating agents (NGOs, Banks, government) and the structure increase the absorption capacity of new innovations.

The Tisza Biodiversity project applied and slightly modified the micro grant scheme, but all key elements has been taken into account (see below)

5.10.4 Micro grant scheme for Living Tisza

5.10.4.1 The development of the micro grant

The development of the micro grant scheme had three main phases. In the following these phases are described with emphases on the integration of floodplain management and climate change adaptation considerations. These phases are:

- *Phase 1*: Micro grant idea incorporation into the UNDP-GEF Tisza biodiversity project (2004-2005)
- *Phase 2*: Design of the micro grant scheme (2005-2006)
- *Phase 3*: Institutional development of the implementation (2006-2008)

In *Phase 1* (2003-2005) the UNDP-GEF Tisza biodiversity project ('*Living Tisza project*') plan was designed, with the support of a UNDP external advisor (UNDP, 2004). The proposal formulation signified a shift in objectives from the preservation of oxbow lakes in the Tisza basin to the introduction of integrated floodplain management. The possibility was discussed to use one third of the available funds for a revolving fund to support local initiatives (based on the Micro credit idea). Due to the GEF regulations, this idea turned into a grant fund (micro grant) that allowed for selection of beneficiaries after contract closure. The intensive discussions on plan implementation had the additional benefit that it convinced the UNDP responsible manager of the appropriateness of the micro credit idea, who then negotiated with the GEF secretariat to allow the planned budget structure and its flexibility. Besides users the idea got support from potential users at the inception workshop.

In *Phase 2* the design of the micro grant scheme started as part of the approved project implementation (2005-2007). The key issues to solve were:

1. Design of the detailed objectives.
2. Find institution which is eligible for financial grant service (bank, foundation)
3. Planning of the criteria and evaluation sheet.
4. Co-design of local institutional development for technical support, peer review and evaluation with participating micro regional teams.

5. Planning of alternatives of the micro grant procedure.

This work was carried out by an expert team within the Living Tisza project, in iterative consultation of the micro regional teams, the project coordinators, potential beneficiaries, external experts (including those of the ADAM project) and UNDP.

In co-design with potential users, *Phase 3* translated the goals of integrated floodplain management to concrete fields of the scope of small-scale projects, which were:

1. Small projects for landscape management such as nature friendly farming activities, wetland rehabilitation, forestry etc.
2. Development of processing and marketing of local products
3. Planning activities helping the development of the local economy and merchandizing local products.

The total budget of the Fund was 205,600 USD. Applicant could receive a grant of maximum 5,000 USD. The initiative sites were: Bereg, Bodrogköz, Kesznyéten and its surroundings, Borsodi-Mezőség, Nagykörű and its surroundings, Kis-Sárrét. Each of the six initiative sites could receive a grant of a maximum of 34,267 USD in total.

The eligible entities were local farmers, local NGOs, local micro and small sized companies, local inhabitants (natural persons). The call for proposals was open from 20 December 2006 - 31 January 2007. The selection procedure took place till May 2007 in 3 main steps (detailed criteria see Section 5.10.4.2):

1. Formal correspondence (Implementing Agency: Partnership Foundation)
2. Compliance with the goals of the Fund (Micro region Action Group Committees – peer review and technical and scientific support for applicants)
3. Ranking by quality (Micro Grant Evaluation council)

The highest-ranking proposals were discussed and approved by representatives of micro regions in the Tisza and the project supervision board (formed by high level administrators from all responsible ministries – the Ministry for Environment and Water, the Ministry for Agriculture and Regional Development and the Ministry for Regional Development and Municipalities).

Implementation periods took 9- 12 months, with continuous monitoring and support by the micro regional action teams and the Tisza Alliance. Financial assistance had been provided by Ökotárs – Partnership Foundation.

Figure 5.33 illustrates the procedure from application and selection to project implementation and control.

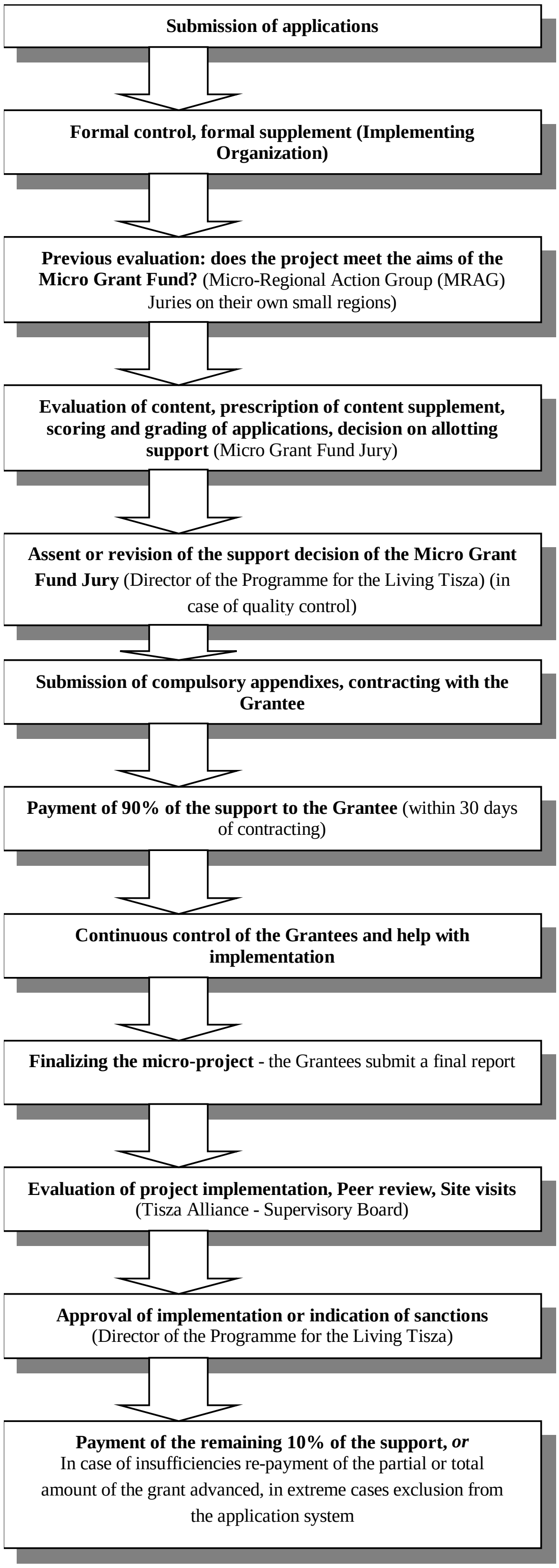


Figure 5.33: Order of application and selection procedure, project implementation control (Kajner et al, 2008)

5.10.4.2 Selection and selection criteria for the micro grant scheme

This section describes the criteria developed for the preliminary assessment by the micro-regional action groups and the ranking by the micro grant evaluation council.

The **preliminary assessment sheet** at micro regional level aimed to be simple and had a dissemination role as well. It consisted of five key questions with binary answer option (yes/no) and scoring for the level of fulfilment. Each evaluation box contains a statement and a short explanation.

Criteria – evaluation of the application	Match objectives	Score
The application support the implementation of the overall principles and objectives of Living Tisza Project (In the Tisza catchments, especially at the 6 pilot sites the project improves the livelihood, increase flood safety, protect and enhance the biodiversity in the region to provide well-being and good life quality for the local inhabitants and those visiting the regions.)	Yes/no	
The application supports the model development of sustainable farming (To support the development and acclimatization of new farming practices, which implement the joined existence of humans and river to achieve wise use of natural resources and processes (eg. flooding), instead of exhausting or over-regulating them. To fit to the natural landscape capacities, enriches the biological diversity and provide happiness and livelihood for inhabitants.)	Yes/no	
The application targets a **habitat development or management by farming**, which preserves or further develop biodiversity as part of the daily routine. (applicable only in case of I.)	Yes/no	
Falls under one (or more) categories I-III.	Yes/no	
The project supports the introduction or broaden *(integrated floodplain)* landscape management.	Yes/no	
Overall assessment: The application fits to the objectives described in the call	Yes/no	

The micro-regional action groups had detailed discussion and learning on priority setting. The experiences of the evaluation procedure was discussed within the All-parties Meeting of the Living Tisza project, after the procedure. Comments include:

- good to have local evaluation since they have access to specific knowledge, such as reliability, availability of own shares, in-kind contribution, capacity on knowledge transfer, cooperation level with other farmers for effective dissemination;
- good to have a higher level body, where local conflicts of interest or other issues can be solved, discussed with more neutral and well qualified people;
- procedure doesn't require much more time and the benefits – eg. learning from others ideas – has a multiplying effect.

The Evaluation council criteria were developed and discussed over a longer time and aimed to brake down the overall objective of the Living Tisza project (the implementation of integrated floodplain management to contribute to overall development of well-being and to preserve or enhancing biodiversity). Nine categories were defined, combining lessons from the application to the agri-environmental schemes or the European Agricultural Policy, international practices and other grant schemes:

1. Motivation, commitment – does the applicant have previous experiences, or totally new in the field (higher risk, but also higher innovation capacity) ~ 5%
2. Typology of projects and potential paragon – extensification takes place; landscape management as a model implementation occur ~ 17%
3. Number of partners in implementation – it was important to set reasonable numbers, so 3 categories were set 0; 1-3; above 4. ~8%
4. Environmental, nature awareness of the proposal – effects or potential effects on biodiversity (high, medium, low) ~17%
5. Effects on the environmental pressures – does it contribute to local- regional global reduction of environmental emissions (soil, air, water) from system perspectives ~17%
6. Preserving workplaces or creating further ones – the ranges were set for the small scale; 0-2; 3-5 and above 6 were defined and got lower weights, understanding the difficulty to have large improvement with such a small grant ~ 5%
7. Contribution to local production development and product development – where the production to supply family demands were scored as well since in case of gypsy families it is a large improvement. Highest score was allocated for those who concentrated at their micro regional markets, aiming to reduce transportation emission and lower energy demand for the production ~17%
8. Integration level of the project to other initiatives – the project links to tourism, handicrafts and other local activates were elaborated, specially building on the knowledge of the local action groups. ~14%
9. Bonus points were provided for proposals dealing with traditional, landscape originated products producers. Also aiming local cyclic approach, were scored, emphasising the need to revisit our farming activities (nutrition cycle, water cycle, waste management, sewage utilization at sites, etc.). Implementing land use change to fit to the landscape potential has been listed as well ~ 4 points (~8%) each

5.10.5 Comparison of Tisza micro grant scheme to micro credit scheme

Table 5.7 compares the Tisza micro grant scheme to the micro credit scheme as it is internationally known. It highlights key similarities and differences.

Table 5.7: Comparison of micro credit scheme and Tisza micro grant scheme

Key characteristics	Micro credit scheme	Tisza micro grant scheme
Groups applying for credit	no or bad credit history, lack of stabile employment, lack of collateral.	no or bad credit history, lack of stabile employment, lack of collateral large depths from previous governmental actions (eg. large machinery loan)
Type of financial assistance	Credit, small scale with interest (12-24%) Small scale savings by member are allowed and part of the operation of the scheme	Small Grant (under 1 million Ft ~ 4000 Euro) due to GEF regulation of the project (in the future revolving fund with small interest under 10%) Savings is not part – the revolving fund could operate only with financial supporters (companies, regional councils, international funds) due to strict

		Hungarian regulation on bank operations
Community cooperation	Self help groups Support in implementation and payment if it is necessary	Micro regions evaluation teams Peer review of projects Support in design and implementation (both professional and community)
Flexibility, complexity, innovation and adaptation objectives	Supports innovations and based on local demands; Flexible Climate change objectives are not expresses	Integrated objectives (see evaluation criteria table); with high social and environmental concerns; linked to CC adaptation and closing local cycles (production, consumption, waste, water management)
Financing institutions available in the country	Private banks representing the interest of investors	Private banks representing the interest of investors State banks with mixed (and sometimes unclear) objectives, including social aspects and vulnerability reduction (eg. Wesselényi Fund)
Project sizes and preferences	World Bank activity in developing countries represents large scale infrastructure-investments rather small scale decentralized solutions Diverse ownership, equity problems	Large scale, single-objective investments, with EU subsidies (highway, dry polder, dam ad dyke improvement; large scale shopping areas) and national interest and tax subsidy. Privatisation of management of natural resources or the resource itself (water, waste, sewage, irrigation forest, land)

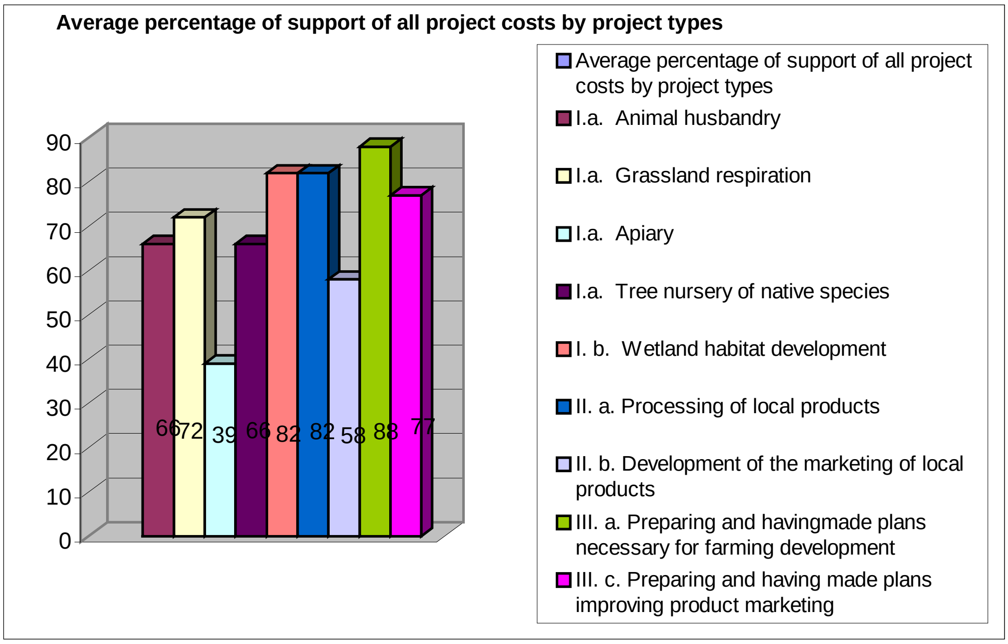
(Compilation based on ADAM interviews and literature survey)

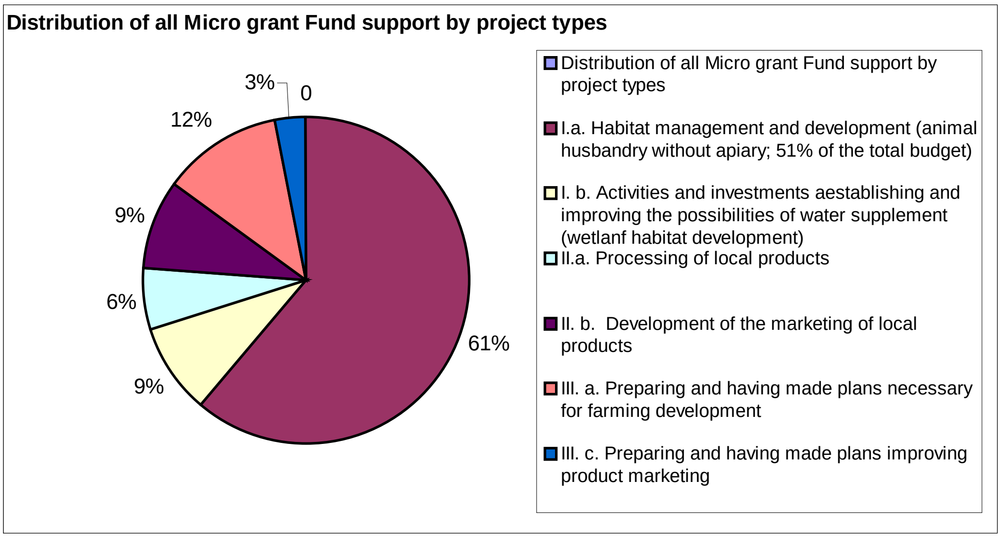
Besides the difference in the financial mechanism (loan/credit vs. grant), similarities can be found. These allow the Tisza micro grant to be changed into a micro credit scheme (revolving fund), with the potential to receive co-support from companies, foundations for the objectives of floodplain management, such as supporting carbon sequestration, biodiversity protection, genetic protection, improving local people livelihood and on long term contributing to sustainability.

5.10.6 Results and discussion of the Tisza Alliance micro grant scheme

Evaluation of the results of the micro grant scheme so far include (Kajner, 2008):

- Contributing to reduce poverty, biodiversity loss and protecting key resources – water, soil, nature
- Awareness raising – at company level, in the Tisza valley, in Hungary
- Contribution to climate change adaptation and mitigation on implementation of the benefiting projects
- Reduce risk for industry and infrastructure in the Tisza valley
- Publicity for small scale (adaptation) measures and micro grant opportunities in the region, in Hungary, in the Tisza river basin (Ukraine, Romania, Serbia) and internationally (UN, EU)
- International aid – tax reduction, benefits





The procedure key elements from the evaluation of the grant scheme are:

1. **two level application**: the process of presenting the idea and all requested documentation has been split. This way the bureaucracy has been reduced and only the accepted ones had to submit requested official forms and signature pages
2. **pre-assessment by the micro-regional action groups**: Improvement of local responsibility and utilization of the trust build up in the local shadow network, quality control by the local action groups took place. It provided both a possibility to reflect their own priorities in the pre assessment as well as learning from the ideas in their own region.
3. **peer-review by micro-regional action groups**: the system has double or even triple learning objective. Beside teaching low educated, segregated actors to use project funds for their aims, also budget planning and incorporation of long term perspectives (such as climate change) had a curtail role in the process. People with different backgrounds and perspectives

on the Tisza and its regions, cultivation methods, alternative income opportunities and cultural background could discuss, debate and learn from each other.

4. **continuous support from the idea till the finalization of the plan:** the project team and the granting agency had an important support function right from the beginning of the initiation and interim visits and online help desk at Tisza Alliance office guarantee the incorporation of the overall objectives of floodplain management.
5. **monitoring of the process:** the core team of the project involving external experts from the advisory board had visited the projects under implementation and asked for modifications, further explanations (or could terminate the project). The process was very useful; several small legislative, institutional and infrastructural problems could be discussed which had been tackled by the Tisza floodplain handbook.

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6 Comparative background studies

6.1 Social Learning on climate change; insights from China, Eastern Europe & Iberia

Abstract (see also full paper (Tàbara *et al.*, 2009))

The building of individual capacities and institutional arrangements to adapt and mitigate climate change can be understood as a process of social learning. From empirical evidence gathered within the EU project ADAM (www.adamproject.eu) we look at climate impacts and responses in form of new social-ecological arrangements, capacities, and agents' transformations derived from increasing climate awareness, risks and opportunities in three regions of the world: 1. The Alxa league, Inner Mongolia, China 2. The Tizsa flood plain, Hungary and 3. The Guadiana river basin, Iberia. Several key factors appear to constrain or enhance climate social learning among agents at the regional level, and in particular: (a) the type and resources for multi-level and cross-sector interaction with empowered agents (b) the institutional and individual capacity of becoming aware, anticipate, and control the negative personal and system's effects of continuing with the existing patterns of social-ecological interaction and development (c) the available degrees of freedom to modify ones' practices and social-ecological interactions while creating a better-off situation from such transformations. In the three regions, climate has become an overarching rationalising discourse of many disparate biophysical changes and economic opportunities, which lead to new climate related actions in a reframing and social learning mode.

6.2 Integrated Climate Governance and sustainable development

Abstract (Full paper in cooperation with work package P1 (Tàbara, 2009))

Following the latest insights gained from the EU funded research projects MATISSE (Methods and Tools for Integrated Sustainability Assessment; www.matisse-project.net) and ADAM (Adaptation and Mitigation Strategies - Supporting EU Climate Policy; www.adamproject.eu), the concept of *Integrated Climate Governance* (ICG) is defined and its normative implications for local and regional sustainable development specified. ICG can be understood as *the structured generation and use of tools and methods for (i) the comprehensive assessment of climate risks, (ii) the design and implementation of policy instruments, and (iii) the creation of communication, engagement and learning capacities, all aimed at producing long-term efficient, equitable and socially and ecologically robust climate strategies. ICG deals both with adaptation and mitigation, as well as with development risks and opportunities, and does so from a multi-scale, multi-level, multi-domain and transition-oriented perspective*. It is argued that ICG constitutes a powerful conceptual synthesis to reframe present EU research and policymaking processes and results on climate change in ways, which increasingly become more relevant to meet pressing societal and policy needs and support goals such as the EU Sustainable Development Strategy.

7 Discussion, conclusions and recommendations

In its assessment of adaptation practices, Chapter 17 of the IPCC's Fourth Assessment Report concludes that: i) adaptation to climate change is already taking place, but on a limited basis, ii) adaptation measures are seldom undertaken in response to climate change alone, iii) adaptation and adaptive capacity are uneven across and within societies, and iv) there are substantial limits and barriers to adaptation (Adger *et al.*, 2007). The results from our three study regions support these insights. In addition to constraints we observe opportunities for mainstreaming adaptation in land use and water management. Below we elaborate on the commonalities and contrasts in the three regions to learn about climate impacts, adaptation practise, and constraints and opportunities for mainstreaming adaptation.

Climate change and impacts on land use and water management. In all three regions, local populations are already experiencing the impacts of a changing climate. The role of context-based science is increasingly being recognised and supported by national and regional institutes (cf. Weaver *et al.*, 2006). In particular, new climate projections are being made available, contributing to regional and political awareness of potential climate risks. So far the primary focus of academic analysis has been on temperature. Improved projections, especially of precipitation and climate related risks like water shortage, remain important challenges. These projections depend critically on the scale and the resolution of the data used as well as on integration of social and political aspects in the evaluation of potential adaptation strategies. Furthermore, there is a need for integration of agro-ecological and economic data into regional climate risk assessments.

Traditional agro-environmental land use systems in all three regions reflect the way local populations adapted to the region's climate variability. These traditional systems have subsided under competition from the global economy and changing institutional contexts. New global market production systems tend to be less adapted to regional climate change and variability and often respond less efficiently to local demands for quality and diversity of services provided. Thus climate impacts cannot be dealt with separately from the increase of scale of economic human activities. Together these aggravate existing challenges for sustainable land and water resources use at the local and regional level. Water shortages in particular highlight the interdependence of water users and the need for interaction between different sets of actors. The emerging interaction can have also stimulate new cooperation as in the case of marrying sustainable tourism with agricultural diversification in the Guadiana and Tisza region.

Assessment of adaptation practices. Adaptation to regional climate variability has always taken place. At present pro-active adaptation actions are planned for future climate change, yet on a limited basis. Adaptation is mostly in the planning stage or implemented through pilot projects. There is no clear connection between regional climate impact studies and adaptation planning. Adaptation planning typically accounts for more general climate trends and scenarios, partly because detailed assessments of climate impacts have only recently become available. Although climate change has encouraged dialogue between different actors and policy communities (for example water and agriculture), actual adaptation planning and implementation remain largely sectoral. So far, the impact of adaptation mainstreaming on the integration of non-climate policies is limited in our study regions. With respect to adaptation planning there is a gap between ambitious policy goals and policy implementation. Whereas adaptation policy goals often refer to transitions to adaptive systems, the instruments selected in the European study regions focus on gradual change and well-established existing practices (dikes, dams, irrigation, risk management, setting targets). In the Inner Mongolia region, land-use policies have been implemented and scaled up rapidly (Runhong, 2001), leading to new adaptation challenges for policy makers and local people.

Enhancing adaptation: constraints and opportunities. While there are substantial constraints to adaptation there are also opportunities emerging. We use six aspects to discuss these: *biophysical, technical, financial, institutional, social, and cognitive and informational aspects.*

- *Biophysical aspects*: In all three regions, ecosystems have degraded and water resources are over-exploited. Traditional landscape and resource use practices, such as the dehesa in Spain and Portugal or the traditional floodplain production systems in the Tisza, seem to have been better prepared to respond to changes in the climate and had an active role in regulating climate extremes. This regulating service has motivated local populations, scientists and policy makers to explore the traditional agro-ecological production systems. Our research in the Tisza and Guadiana river basins show that preserving and managing diversification of land uses has a great potential for reducing climate related risks. In the Tisza region diversification of land-use in relation to the hydrological conditions is explicitly supported by the current water management plan.

- *Technical aspects:* Existing technical solutions, like building dikes, run into limits or add to undesirable downstream or longer-term effects. Pilot projects and demonstration activities have started to test the feasibility of new technologies for sustainable land use and the development of natural resources. There is scope for the development and exchange of more sustainable technologies and information systems, including early warning systems (for example the cell phone based warning service in Inner Mongolia). Small-scale adaptations to provide shade, break wind or harvest rainwater deserve more attention in local planning and design. Currently available integrated assessment models are not parameterised for assessing new technologies and more complex and innovative adaptation strategies, creating a barrier for the appraisal of mainstreaming.

- *Financial aspects:* Financial resources are limited in each of the study regions and adaptation is often considered too costly and uncertain compared to expected benefits. Whereas there is a pressure on existing financial services (for example insurance) to become more expensive, new financial instruments are also emerging (like micro-grants). The implementation of adaptation strategies is constrained by unequal distribution of costs and benefits. For instance, measures taken to reduce land degradation and sand storms may conflict with rural livelihoods and be financially unsustainable, and water retention increases the risks for those who store the water for the benefits of others. At a smaller scale, the difference between those who are, and who are not, included in adaptation pilots or support programs can increase tensions. The perception of fair sharing of costs and benefits between actors is central to the successful implementation of adaptation and has to be addressed in adaptation planning. In all study regions, European and/or national government financial support is sought for the implementation. However, mainstreaming adaptation complicates existing relations with donors or subsidies. The European agro-environmental schemes for instance are not designed for inter-annual land use change depending on water availability. Creating markets for adaptation is a key challenge for the Tisza region (for example encouraging cities and industries to buy in on upstream flood water storage and floodplain management) as well as for national and international adaptation to climate change. All three regions identified opportunities for public-private partnerships in which marketable products obtain additional public support in exchange for providing social and environmental services that support adaptation. Agro-tourism is promoted in all three regions as a means to diversify the economy, reduce climate related risks and create opportunities for both tourism and traditional land use practise.

- *Institutional aspects:* Divided and unclear responsibilities are key constraints for adaptation actions in the Guadiana and the Tisza river basin. By contrast, in Inner Mongolia the rigidity of the strictly defined roles of different organisations is considered a constraint, as well as the limited communication of intended policy goals to beneficiaries. In all three regions we saw a lack of co-ordination between agencies and tensions between actors at different scales. Mainstreaming adaptation and embedding it in existing national policy and institutional frameworks allows for addressing trade-offs and synergies that are crucial for 'selling' adaptation. Yet it complicates the implementation of the original policy and diffuses the responsibility for implementing the adaptation agenda. There is a clear call on central governments to delineate and communicate the roles and responsibilities for implementation of adaptation strategies at national, regional, and local levels. To achieve more adaptive governance structures capable of dealing with new risks and uncertainties, different scales of governance need to work together to make policies, plans and programmes more coherent. Stable adaptive governance is a complicated paradox. Adaptive governance is a relatively new concept that needs to be demonstrated to gain in appreciation. Inspiring examples are the emerging coalitions of government and non-government actors that are helping to put the adaptation agenda in a regional context and encouraging action in the region. Successful coalitions often have close connections to academics who act as brokers in the communication of climate risk and adaptation information. Our analysis in the Tisza region shows the importance of recognition of adaptation at an abstract level by responsible civil servants and advocation of an adaptation strategy by a credible regional coalition. The recognition of adaptation and political attention following a number of major (near) floods, provided a window of opportunity for changing land use and water management. Opposition is inherent to implementing more fundamental policy change and engaging with (potential) opponents is an important activity in adaptation planning.

- *Social aspects:* Adaptation can fail or be counterproductive because social processes and structures are imperfectly understood. Some adaptation options have consequences that are socially unacceptable. In the Tisza basin for example sites for water retention were rejected. In the Alxa region, the enclosure of livestock conflicts with traditional lifestyles. The Tisza study region shows that informal social networks around local production systems have degraded, but are remediable. Local populations hold a wealth of knowledge on how to cope with climate variability, which deserves to be taken into account while developing new policies and measures. In addition, strengthening diverse local capacities offers opportunities for income diversification though for example agro and culture related tourism. Adaptations include the promotion of festivals and fairs in periods that are attractive and comfortable for tourism.

Cognitive and informational aspects: In the Alxa and Guadiana regions in particular people struggle to connect regional trends to global climate change. The causes of trends in desertification and reduced water availability are heavily contested. Adaptation policy so far does not address the diverse perceptions of risks and their causes. The Tisza region shows benefits of debating climate related risks and how best to respond. After various discussions on adaptation options, actors were quick to take advantage of a micro-grant scheme for implementing local solutions. This supports the notion of adaptation as a social learning process. Another lesson is to implement cost-effective and flexible adaptation frameworks, which can be modified as personal and scientific understanding changes. All three regions suffer from a lack of (access to) information about new adaptation options and policies. Knowledge integration can take place through 'issue-linking' in debates (for example in the case of linking climate change to desertification). Newly emerging forums for debating adaptation strategies may prove to be valuable in this regard. At the regional level these are often associated with internationally funded projects, experimenting with new forms of engagement between scientists, policy makers and the wider stakeholder community. An opportunity for planning is to focus on the transfer of knowledge relevant for adaptation decisions including early warning systems.
Yet, a gap remains between scientific adaptation theory and adaptation practice on the ground. There is a mismatch between model assessments of impacts and adaptation on one hand and 'real' adaptation options as discussed by people in the region or in the policy plans on the other. For example, existing models in the Tisza and Guadiana Basin do not include resource conflicts resulting from multi-stressors or win-win opportunities resulting from the integration of adaptation and longer-term sustainable land and water use planning. As such, there is an observable tension between the information demands of the implementation process and the support that scientific modelling frameworks offer (cf. Vogel *et al.*, 2007).

Summarising, opportunities for using land use and water management planning to support adaptation and climate-proof regional development have started to emerge. In all three regions we identified institutional and cognitive aspects as crucial for implementing adaptation successfully. The degree of success critically depends on the capacity to participate in adaptation and the distribution of that capacity across different actors and governance levels. This includes, for example, access to information, governance and financial services. In all three regions, lessons can be learned from integrating traditional agro-environmental land use systems with new technologies and institutional designs, for example to preserve diversity in landscape, ecosystem services and land uses. The study regions suggest that it is important to balance formal regulatory rules and informal social factors in planning and implementation. Informal networks are crucial for social learning and adaptive capacity and may be particularly useful in times of crisis. At the same time, formal rules are required to include adaptation in longer term planning, investment and financial support of experimentation and adaptation.

The six aspects of adaptation discussed capture the constraints and opportunities for mainstreaming adaptation in land use and water management well. While the relative importance of each aspect is location specific and will vary over time, our research conveys that consideration of all aspects is needed to capitalise on opportunities for planning and implementing adaptation successfully. Our study regions therefore suggest that next to adaptation mainstreaming there is a need for a comprehensive and systemic adaptation agenda, reaching across sectoral non-climate policies and programs.

Based on our research in the Guadiana region, Inner Mongolia and the Tisza region we offer the following recommendations for mainstreaming adaptation in land use and water management.

Adaptation to climate change is enhanced by:

1. Biophysical, technical, financial, institutional, social, *and* cognitive / informational aspects of adaptation. In particular: clear implementation responsibility, flexible financial instruments, benefit and burden sharing, social learning and (transboundary) cooperation.
2. Adaptation pilot projects and regional coalitions that test and debate a diverse set of new ideas. Pilots can deliver both on process and outcome.
3. New forms of engagement between scientists, policy makers and the wider stakeholder community.
4. (Traditional) agro-ecological production systems and landscapes that regulate climate impacts.
5. Concrete adaptation plans to share with government and donor agencies when the opportunity occurs.
6. Instruments that support a diverse set of potentially better-adapted new activities rather than compensate for climate impacts on existing activities.
7. (Free and) easy access to information on climate impacts and adaptation options.
8. Process-based models for assessing adaptation strategies.

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