GAWI ISSUE PAPER No 2[1]

Enhancing ecosystem services through agro-ecological water management

Introduction and background

This issue paper supplements the GAWI framework document and supporting material, with the specific aim to feed the discussion on what the guidelines for sustainable agriculture wetland interactions should address, and what not, as well as a structure it could adopt. To this end the paper builds upon the framework document and the GAWI case-data base where possible. It explicitly links the adopted framework of the DPSIR and its implication of developing congruent multiple response strategies to the analysis and recommendations of the MA and CA, which both treat upon the GAWI topic. Attempts have been made to define the scope for guidance from both sides of the topic – what can be done from and by the agriculture sector and what by the wetlands and environment sector. The challenge and central task for GAWI, it is argued, is thereby to: (i) set an overall framework and approach (based on DPSIR) to provide a clear shared understanding and common targets among the two sectors; (ii) clearly sets out what good and suitable guidance each sector already has on offer to reach these targets; (iii) defines the gaps and issues in the common ground and targets that need further attention.

The original title for this paper, as kept in the current edition, defines the ambition to define the common ground. The ambition still stands.

[1] By Gerardo E. van Halsema (WUR) and with Data-base support by Hans Langeveld (WUR) and Herco Jansen (WUR) who provided the section on water purification.

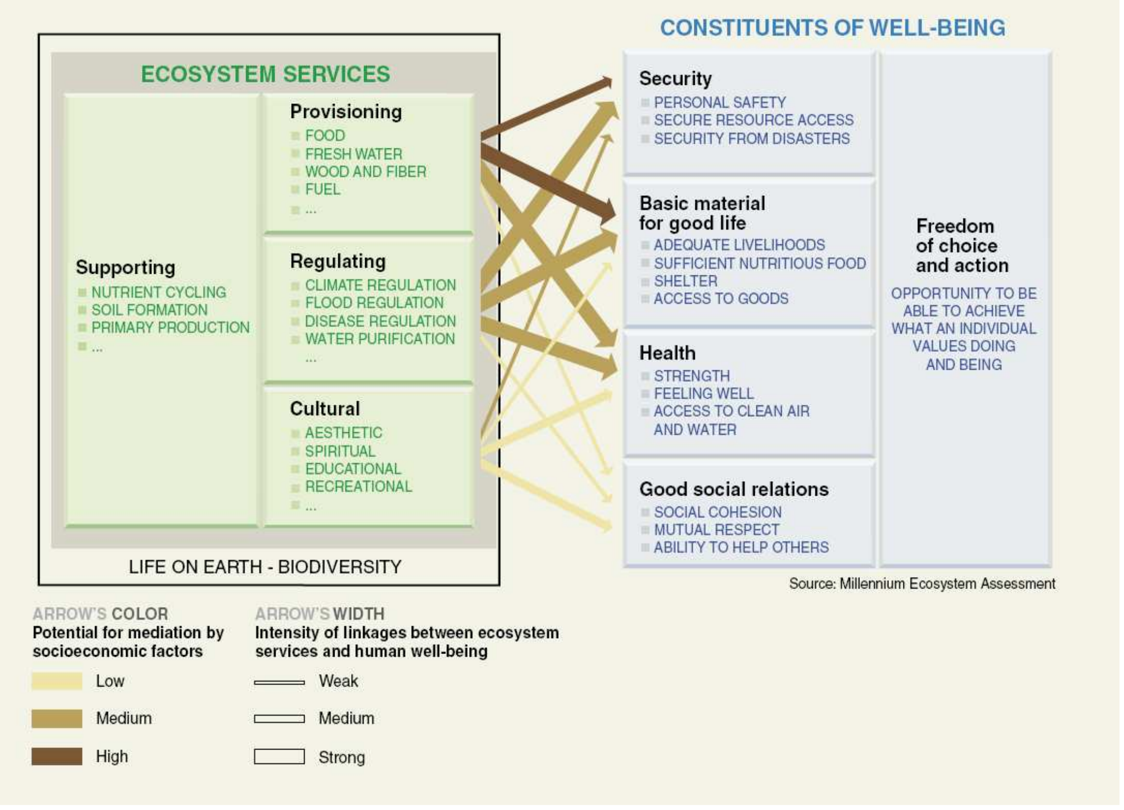
1. Ecosystems services and their multiple demands for agro-ecological water management.

Ecosystem services

The concept of *ecosystems services* has been well established and elaborated, especially since the completion of the Millennium Ecosystems Assessment (MA). Since the latter's completion the concept has also been formally adopted by the RAMSAR convention as a principle framework for wise use of wetlands.

The concept neatly encapsulates the multiple facets of complex ecosystems through the introduction of a typology of *ecosystem services* (see figure 1): (i) provisioning services as food, fiber, fuel and water; (ii) regulating services as flood regulation and water purification; (iii) cultural services as spiritual and recreational, and; (iv) supporting services as nutrient cycling. Wherein the first three are directly useful or beneficial to humans or human well-being as they provide the primary means for production, natural resources management, and spiritual well being. The fourth one is clearly distinct in constituting services, or natural processes, that are required to maintain the ecosystem and/or have a distinct function in natural resources cycles.

Figure 1: Ecosystem Services & Human Well-Being



(Source: MA 2005a)

Sustainability
This ecosystem services framework implies[2] that sustainability – defined in terms of healthy ecosystems that sustain human well-being – requires that a certain balance is attained and maintained in the multiple services – both inter and intra service typologies – that are derived from the ecosystems and the natural resources base. Over-dependency on one, or a limited number, of services and type is the major cause of trespassing the carrying capacity and resilience of the ecosystem itself; and thereby of its degradation and eventual "extinction". Whereby not only the ecosystem itself, but also the services it could provide, are severely degraded or lost.

The MA (MA 2005) asserts that over 50 percent of specific types of wetlands in selected regions of the OECD were destroyed during the twentieth century, and many others in other parts of the world degraded. The primary drivers and pressures of degradation and loss that continue to threaten wetlands today are closely associated with the (over) exploitation of provisioning services as food, fuel and water:

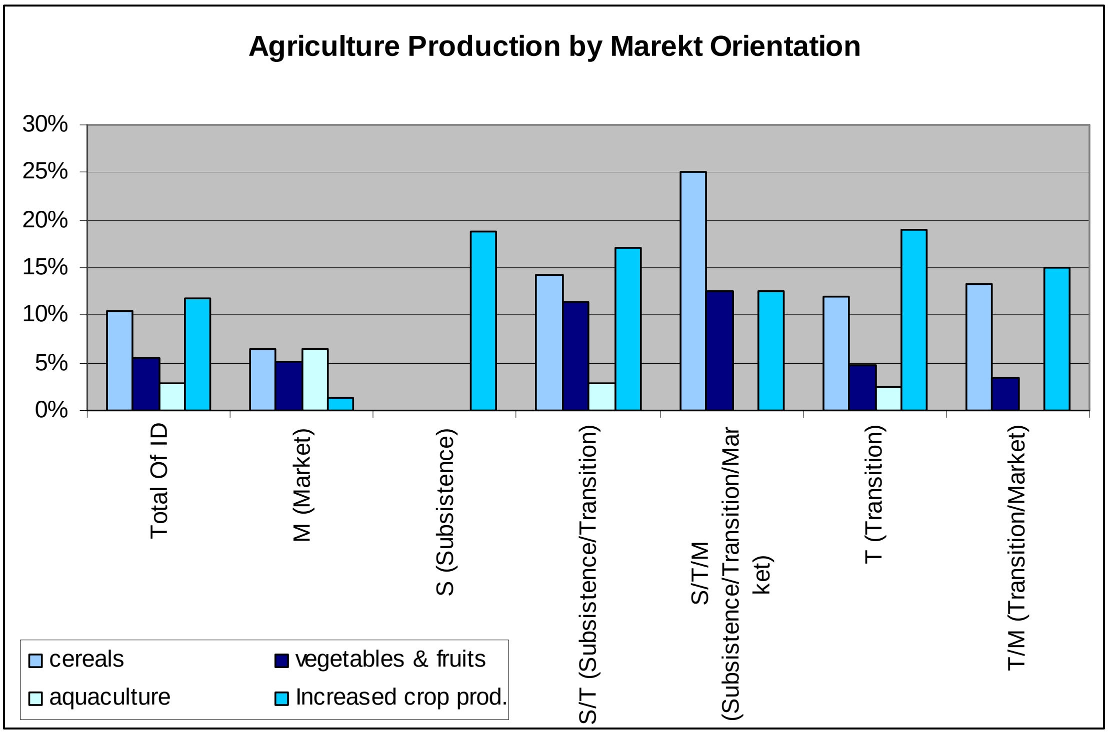
- Development of infrastructure
- Land conversion
- Water withdrawal
- Over-harvesting & over-exploitation
- Introduction of invasive species.

The negative impacts of these drivers have been significantly exacerbated by the optimization and maximization of, in particular, agriculture, whereby the resources base and environment is purposely optimized to serve food maximization – e.g. water control infrastructure, drainage and land settling, fertilizer and pesticide use and associated pollution, etc. Whereby the impact of these on the other specific functions and services of ecosystems – or even the system at large – has been frequently disregarded and/or uncontrolled.

The GAWI analysis of drivers, pressures, states and impacts of agricultural interaction across wetlands corroborates this picture of skewed services exploitations in and around wetland ecosystems. It are mostly intra-typology specific service (such as rice cultivation, aquaculture, irrigated vegetables, etc) that dominate the exploitation of ecosystems by human society, and throw their mark upon the sate of the system and its impact on society. Frequently this exploitation of one, or a limited set, of specific provisioning services is further re-enforced by increasing market access and/or demand for the provisioning product in question, which further catalyses a skewed exploitation of mono-use of ecosystem services. (See figure 2)

[2] The notion implies is used here, because the framework of ecosystem services provides a simplified concept of the services that can be derived from the ecosystem. Whereas the ecosystem itself constitutes a complex of natural sub-systems (or entities) that together constitute the system. Individual services (intra typology) will directly impinge on a limited and distinct set of these sub-systems, rather than the whole system itself. That is, until the thresholds of resilience and carrying capacity are reached. As the MA framework is focused primarily on the societal issues of human well-being and development, the latter is not dealt with in its complex detail.

The challenge for sustainability is thus to re-dress this skewed exploitation of services by enhancing the other services into a balanced state in which the ecosystem can thrive and sustain the multiple services it has to offer.



Services: rendered or derived?
Remarkably, and crucially, one important element of the ecosystems services framework has remained un-discussed – at least in the explicit MA documents. The central focus of the MA framework and assessment is on the ecosystem ***services***. But whether these services are being rendered by ecosystems, or rather derived from ecosystems by segments of human society, remains implicit. At first sight this might seem a rather pedantic and semantic discussion, but this issue masks a rather elemental differential point of departure – which is better known as the old dichotomy of conservation vs development.

The conservation perspective is inclined to take the stand that the services are provided by ecosystems. As such, the concept has been eagerly and rapidly adopted by conservationists. It namely provides a beautiful argument to focus on the rich diversity of services that benefit human well-being, and hence – so goes the argument – neatly augments the good reasons and economic value to conserve and care for ecosystems.

The socio-economic development perspective will take the stand that services are derived from ecosystems by segments of human society. Which of the rich diversity of services potentially on offer will then be deemed exploitable[3], and thus be actively derived through human intervention, will then primarily depend on the purposes that are deemed worth and feasible to pursue.

The elemental difference lies thus in whether the latent services of ecosystems that may (or are) providing benefits to human well-being, but are not yet valued or perceived as exploitable, are intrinsic to ecosystems or need to be construed by society. This has direct bearing on the notion of sustainability as defined above. Is sustainability primarily a matter of increasing society's appreciation of the thus far latent services? Or, primarily a matter of innovating the exploitations of ecosystems so that a richer, more diverse and balanced set of services are being derived?

This is not to open up an old debate and dichotomy which has been attempted to be bridged with much effort. The merit of the ecosystem services concept lies in sensitizing us to and defining the latent services of ecosystems. Thus enabling us to better explore how these services can be harnessed through innovative exploitations to reap specific benefits, for specific beneficiaries – or customers in services parlance. The challenge lies thereby not only in finding innovative exploitations, but equally in finding responsive customers – i.e. in creating markets or demand for those latent ecosystem services that have hitherto been left to linger.

PES: Innovative market exploitations

The promotion and establishment of payment for environmental services (PES) schemes has taken a great flight over the past decade as such a method of innovative exploitations. Its great attraction lies in the financial mechanisms it provides to reap financial benefits for traditional latent services – particularly regulatory (water regulation, flood control and purification) and cultural (recreation and tourism) services – from direct beneficiaries (or service derivers) to service providers.

The success or failure of a PES scheme is based on the ability to "create" a market – where the demand for a specific service and its benefits can be met through supply – that is based on tangible economic benefits, and not on intrinsic or total economic values including externalities. In successful cases where regulatory services as water purification and flood control are purchased (e.g. the Katskill scheme in New York, Evian in France, Dutch flood Policy) the tangible benefits are mostly found in averted investment costs – e.g. in water purification plants, loss of marketable water source and in upgrading river dikes, respectively. (*cf.* UNECE, 2007*)*

While at the land and natural resources use level, successful PES should provide an alternative means of exploitation that provides economic incentives (or purposes) to use and manage the resources purposely for the provision of regulating and/or cultural services. The trick of PES is thus to transform latent regulatory/cultural services into alternative provisioning services that provide land and resource users with an alternative provision in economic livelihood. If successful, such PES can be a powerful tool in re-

[3] Exploit is used here in its first meaning: "to make productive use of (syn. Utilize)" (webster on-line), and thus not (necessarily) meant to imply any connotation with exhausting resources.

balancing of the ecosystems services exploitation into a more sustainable equilibrium, as long as it provides tangible and competitive alternatives to the traditional provisioning services and same beneficiaries. However, in this latter aspect still lies the catch up till now; the level of financial compensation offered by PES schemes for environmental land uses[4] is still frequently considerably less than that which can potentially be obtained through the exploitation of single provisioning services (*cf.* Kiersh, Hermans, van Halsema, 2005*)*. Questions are thus still raised on whether PES can truly (i.e. fully) provide for alternative economic means from regulatory and cultural services in competition with traditional provisioning services. And thus, whether PES are not primarily means of providing (additional) economic benefits to land uses that are already predominantly earmarked for environmental uses.

The latter may provide, however, an opening for wetlands in middle and low-income countries that are being used for livelihood support through diverse exploitation of provisioning services. If PES can be devised that provide for supplementary monetary income to wetland "inhabitants", in addition to the livelihood means they derive from a diversity of provisioning services, an economic insulation may be provided against sliding into a market oriented over-exploitation of a single provisioning service in the future. The pre-condition is that the PES indeed thus provide for additional income to the local stakeholders.

Water Management

The water resources base to be managed needs to support (whether in quantity, quality or timing) the myriad of provisioning, regulating and cultural services of ecosystems, and the concomitant economic or beneficial uses made thereof by segments of society (or stakeholders). In addition it needs to provide habitat for supporting services.

From an ecosystems perspective the target of sustainability is thus defined in terms of maintaining the wider agro-ecological system that is able to support the diverse ecosystem services, and the beneficial uses made thereof. From both the MA and our own framework analysis the tendency is clearly contrary to this stated goal, in that the integrity of ecosystems is severely undermined by a skewed exploitation of selective services. Restoring the integrity of ecosystems thus becomes primarily a re-balancing act of restricting over-exploited (and over exploitative) services and revitalizing under or non-utilized ones. We explore here what this means for the filed of water regulation and management -- in terms of how water management may actively support this re-balancing act, and what this would imply for the field of water management.

Services vs stakeholders

The current paradigm of Integrated Water Resources Management (IWRM) is stakeholder centered. As such its point of departure is the multitude of stakeholders and the beneficial uses they (currently) derive from specific ecosystem services. These are then brought together through IWRM processes, platforms and regulations, through

[4] E.g. specified forms of land use that are deemed to enhance the regulatory and supporting services of ecosystems.

which the multitude of water requirements from different sectors and stakeholders[5] are sought to be harmonized and met. Within this paradigm of IWRM ecologist and conservationist have made great efforts and strides to include the environment and ecosystems as a stakeholder in itself. A stakeholder which should consequently than be served by a formal water right and allocation of its own, by means of establishing environmental base-flows. After which the negotiations primarily centre around how much nature should be served to provide for so much environmental benefits – usually specified in terms of intrinsic and supporting services that benefit society at large. Whereas from an ecosystems approach the point of departure is the rebalancing of ecosystem services and congruently the beneficial uses that can be made thereof.

From the framework analysis it already became evident that different ecosystem services will in their specificities be used beneficially by different stakeholders. A re-balancing act of ecosystems services to be supported and exploited thereby thus also implies a re-allocation of beneficial uses and benefits among stakeholders. In this issue paper the focus is on how water management may serve the re-balancing of ecosystem services, and the potential beneficial uses that may be derived thereof. How, or even whether, then different users (i.e. stakeholders) can be conformed to reap the benefits of the multitude of services within the limits of the carrying capacity is another issue, which will need to be addressed at the level of drivers and pressures which influence stakeholder and natural resources uses.

[provide examples of re-alignment meaning re-distribution form data-base?]

Aligning services for agro-ecological water management

The challenge and target is to enable a multitude of different ecosystem services (both within and across categories) to be used and economically exploited from the same water (or natural) resources base. As has become evident from the MA, CA and framework analysis, this will require the promotion of some and the restriction of others. However, this is not a mere matter of re-balancing a multitude of water uses to available supply, *cq.* source. The challenge is to harness the water requirements or uses of some ecosystem services to provide for the others – i.e. utilize ecosystem services as a water management tool to provide water for others. The obvious example being where regulating services (e.g. flood control and water purification) are purposely put to use to manage water (i.e. regulate and control) for provisioning services as fisheries and water supply and cultural services as tourism and recreation.

This does not imply that with agro-ecological water management we can pursue and enable win-win situations at all times. This is only feasible in those contexts where the population or livelihood pressures do not exceed the carrying capacity of the system. And even then, trade-offs are likely to be made between benefits and beneficiaries.

It does, however, require a change in regarding ecosystems – it should no longer be equated with (pristine) nature, but be viewed in its functionality to manage water and

[5] E.g. agriculture, industry, water supply, hydro-power etc.

resources for multiple services. The implication being that, for instance, wetlands may be altered, or even created, to better serve specific functions/services as water regulation, purification, fisheries or recreation. This line of reasoning thus implies that the hydrological functionality of wetlands is put at the forefront as constituting those regulating services that are to be beneficially exploited, after which the additional services (e.g. provisioning, supporting and cultural) that can be derived both beneficially and sustainable are explored and developed[6]:

I. Define the characteristics of water regulation functions (or services in MA parlance) that can be put to purposeful water management use in river basin, or large scale irrigation, management;
II. Select and define the wetland(s) – whether natural, altered or man-made (or revitalized) – and devise a land-use and wetland management plan that is specifically geared towards the "creation" and exploitation of the purposeful hydrological function(s) that are targeted for.
III. Devise a wetland management plan and exploitation strategy that is specifically geared towards maximizing the "permissible" exploitation of multiple ecosystem services – in particular provisioning, cultural and supporting – that can be derived from the wetland without undermining the hydrological (regulating) services targeted for.

In terms of agriculture-wetlands interactions (AWI) *agro-ecological* water management would thus encompass a twin-track approach:

(i) the hydrological services to be exploited from wetlands are to provide specific water management functions at the basin or command area level, thereby servicing hydrological requirements of other land and natural resources uses up- and/or down-stream – i.e. high production (irrigated) agriculture, water-supply and urban safety. The hydrological services are thereby thus to be exploited to establish positive 'indirect' interactions between wetlands and other land and resources uses up- and downstream river basins or command areas (*cf.* Chapters 1 & 2 of FD).

(ii) Whereas the 'second stage'[7] of devising exploitation strategies of multiple provisioning, cultural and supporting services are thus specifically geared towards establishing positive *in-situ* and *periphery* interactions between wetlands, agriculture and other uses.

From an agricultural point of view (i.e. the provisioning services exploitation) response strategies will also need to be differentiated along these twin-tracks:

[6] In practice, of course, some limitations to the regulating hydrological services may be imposed that stem from boundary conditions of the other services – in particular supporting and cultural.

[7] 'Second stage' is used here to indicate that the land-use and management strategy for the wetland is in first instance geared towards optimizing the indirect hydrological services in the basin or command area; from these boundary conditions and thresholds are subsequently derived to establish the permissible in-situ and periphery exploitations of multiple provisioning, cultural and supporting services.

(i) At basin-level interactions, agricultural intensive production (land-use specialization of mono-services) will need to focus on establishing Good Agricultural Practices (GAP), that are specifically geared towards delimiting agriculture's negative (downstream) impacts on resources and services exploitation (e.g. water pollution and abstraction, sedimentation, etc).

(ii) Whereas the second track of devising sustainable exploitation strategies for multiple provisioning services of *in-situ* & periphery wetland agriculture systems still remains something of a blind spot in current mainstream agricultural R&D. In order to enhance this field there is a clear need to explicitly focus on agro-ecological production techniques that enhance the agricultural production from ecological environments and resources that are and cannot (or are not desired) purposely managed to enhance "mono" agricultural production systems. Whereby the recent development of new 'NERICA' rice variety is a good example of the exception. (*cf.* IAC, 2004)

Water for Food and Ecosystems
This twin-track approach to water management and wetlands embraces the key principle of the Water for Food and Ecosystems approach:

"To adopt more of an ecosystems approach to agriculture [track II] *and more of a productive services approach to ecosystems* [track I]."

(*cf.* FAO/Netherlands conference on water for food and ecosystems www.fao.org/wfe2005)

It also fits the policy recommendations 1 and 3 of the Comprehensive Assessment:

"Change the way we think about water and agriculture."

"Manage agriculture to enhance ecosystems "

(*cf.* CA 2006)

The role of wetlands for water management:
The argumentation to deploy the hydrological functions of wetlands as '*ecological infrastructure*' for water management in IWRM (as implied by track I above) would seem entirely in line with paragraph 26 and Guidance E.1 – E.4 of the RAMSAR guidelines on IWRM (*cf.* RAMSAR Handbook 7). However, regrettably this does not seem to have been followed through to its logical consequence since its adoption in 1999. Subsequent developments in guidelines and handbooks have been shifting back into the conservation argument – where wetlands are regarded as sources of water that need to be preserved, rather than wetlands as possible 'tools' in water management with which multiple ecosystem services can be sustained. The fundamental difference being that where hydrological functions are advocated as additional reasons (to those provided by supporting, cultural and selected provisioning services) for the conservation of wetlands, these hydrological functions can often be better provided – both in terms of capacity and management function (i.e. water control and regulation) – by water regulation infrastructure. Whereas in terms of track I above, the enhancement of the hydrological capacity and management function a wetland has potentially to offer, is brought explicitly to the forefront as the primary beneficial wetland function, and to exploited to its full potential.

Ramsar IWRM Guidelines on the Role of Wetlands in IWRM:

Section E

Guidelines for Contracting Parties relating to assessment and enhancement of the role of wetlands for water management

E1. Information on functional and biodiversity assessment methodologies and the means for their integration for wetland management should be compiled by the Scientific and Technical Review Panel (STRP) of the Convention and disseminated to Contracting Parties, for their adaptation to local situations.

E2. Undertake studies to identify the functions and benefits to water management which are provided by the wetlands within each river basin. Based on these findings, Contracting Parties need to urgently protect, through appropriate actions, the remaining wetland areas which contribute to water resource management.

E3. Consider the rehabilitation or restoration of degraded wetlands, or the creation of additional constructed wetlands within river basins, to provide services related to water management [(refer to Resolutions VII.17 and VIII.16)].

E4. Ensure adequate consideration in river management programmes of non-structural flood control methods which take advantage of the natural functions of wetlands (for example, restoring floodplain wetlands or creating flood corridors) to supplement or replace existing flood control infrastructure.

(RAMSAR Handbook 7; p.20)

Scope for agro-ecological water management and GAWI guidance:
As with the general objective of the GAWI initiative, the scope to provide for guidance on sustainable agriculture-wetland interactions needs to be targeted to areas and fields that are (a) feasible and, (b) deemed desirable. This scoping for which, what and who are meant to be addressed with the GAWI guidelines in general, and the sub-set of agro-ecological water management in specific, can (and needs) to be conducted on several grounds.

The "middle" ground:
In view of the old divide between nature conservation vs development (i.e. wetlands vs agriculture) there is little scope to address either of these two extremes with the GAWI guidelines – or for that matter imply a "middle way" that can encompass the whole range from pristine wetlands to agricultural production systems. There are ample good reasons to pursue a conservation strategy for biodiversity hot-spots, which have been adequately and ably pursued by RAMSAR ever since its inception. Likewise, the development of agricultural production "hot-spots" are adequately covered and pursued by the agriculture sector.

The primary issues hereby relate to natural resources and land-use planning, and for the case of agriculture a continued pursue of more efficient resources use (especially water and nutrients) and higher productivity; and further limitation/mitigation of negative impacts (*cf.* CA 2006). It should be noted that in this light the frequent occurring and mentioned state changes of land conversion to agriculture and water abstraction are to some degree inevitable trade-offs of land and resources specialization. [cf. Data-base]

Although a conservation strategy may be able to secure valuable islands of biodiversity rich in supporting, cultural and regulating services as well as selective provisioning ones, the MA identified the largest and continuing loss of wetlands in the large 'middle ground' of "ordinary" aquatic ecosystems (*cf.* MA 2005 (a&b)). Whereas the CA indicates that this is likely to continue over the next five decades, as the global demand for agricultural production is still set to double – which will require additional land and water resources to meet (*cf.* CA 2006). And the latter is increasingly set to be taken from suitable 'ordinary' ecosystems.

Defining the middle ground
For the purpose of scoping, the large "middle ground" of "ordinary" or common aquatic ecosystems that are set to interact with agriculture will have to be defined in a more specific manner. A possible way to do this, is to take table 3.1 of the MA wetlands synthesis (MA 2005 b) as a basic wetland typology, and assess in more detail the suitability (and likelihood ?) for agriculture interactions to develop over the next decades. This should yield a considerable narrowed down typology of wetlands (30 percent of table 3.1?)

The hydrological function
Specifically for the case of agro-hydrological water management, the suitability or capacity of wetlands to provide for hydrological functions, or regulating services, will have to be defined and assessed.[8] In terms of functionality for IWRM as *'ecological infrastructure'* only a limited set of hydrological functions are of specific interest to provide for basin level water control and management capacity:

- *Flood control and protection*. The most common and prominent form of these services are provided by flood plains and forest-based aquatic ecosystems in coastal protection.
- *Water storage and regulation*. These hydrological functions form one of the core water control and management tasks of IWRM. However, little attempts and progress has been made so far in trying to provide these services through the establishment of *'ecological reservoirs'*. The notably exception being tanks within irrigation schemes (*cf.* Kyrindi Oya case chapter 8) that over time get to be regarded as man-made wetlands and aquatic ecosystems.
- *Water purification*. The capacity of wetlands to act as effective sediment traps and sinks for toxic pollutants and nutrient loads is well acknowledged, in particular among the water supply and beverage industries that have a high stake in this field. It is also the hydrological function/service around which by far the most PES schemes have been established. It should be noted, however, that also agriculture can provide these services to some extend. Especially as a sink of nutrient loads in waste water (providing protection against eutrophication).

The literature and debates surrounding hydrological functions and services of wetland ecosystems also incorporates other services. Especially functions regarding the regulation of water quantities – e.g. groundwater recharge; the 'sponge' effect and dry-season base flows, wetlands as a water provider, etc. – incite a lot of interest and contested views. As ecosystems still account for by far the largest evapotranspiration in the hydrological cycle (*cf*. CA 2006), the end balance between water provision and consumption tends to be less favorable than anticipated by some protagonists (*cf* Bullock & Acreman, 2003 and FAO, 2005). These are therefore not recommended to be pursued in guidelines for agro-ecological water management of GAWI.

Defining the hydrological potential of wetlands
A similar methodology as above could be applied to define the hydrological potential of the MA/RAMSAR wetland typology, thereby identifying wetlands that could be targeted to provide hydrological services for IWRM at basin level.

[8] As above, preferably on the basis of existing typologies as of table 3.1 of the MA-wetland synthesis. But this seems to have been called for 1999 to be provided by the STRP.

The Agricultural Guidance
For the development of guidance on agro-ecological water management, as on the GAWI itself, the question beckons how far we, and RAMSAR, should encroach on to the field of agriculture. It is suggested to inform this answer on the basis of the twin-track approach outlined above:

- *Track I Indirect basin level interactions:* In this area of AWI the primary focus is on establishing agricultural practices that significantly diminish or abolish the negative impacts on wetlands. Within the field of agriculture these are referred to as Good Agriculture Practices (GAP), which already cover a wide variety of specific impacts and interactions, a.o.:
    - Conservation Agriculture – targeting soil erosion (sedimentation) and infiltration;
    - Integrated Pest Management – targeting agro-chemical pollution;
    - Waste water use in agriculture – targeting nutrient recycling;
    - Etc. (not only limited to crops but also covering livestock and aquaculture)

- *Track II In-situ and periphery limited provisioning services:* In this area of AWI two agricultural scenarios can be distinguished:
    - Documentation and dissemination of "indigenous/local" practices and techniques of exploiting multiple provisioning services within the ecological boundaries of wetlands (*cf*. FAO 2003);
    - Setting of a Good AWI agricultural R&D agenda, where the emphasis is laid on the enhancement of provisioning services through a more varied use of species and varieties that are explicitly suited for the agro-ecological and hydrological conditions and limitations set for the wetland. E.g. NERICA for upland and rainfed rice, agro-forestry (?), revitalization of floating flood rice varieties, assisted fish stock rejuvenation, recession agriculture (specialized varieties and supplementary irrigation), etc.

An intrinsic difficulty under track two that needs careful judgment is the degree to which the Good AWI practices pursued may be replicable across aquatic ecosystems. The suitability should not only be defined in terms of hydrological regime, but also in wider agro-ecological conditions.

The agricultural guidance
In terms of the GAWI guidelines there is a clear need to guide the audience towards appropriate technical content of suitable agriculture response strategies that may be incorporated into an overall response strategy to any DPSIR analysis – The latter following strongly from our methodological guidance.

In terms of agricultural content guidance it is, however, questionable whether GAWI and RAMSAR should venture into this field. As far as track one guidance on GAPs to improve basin level indirect AWI is concerned, the suggestion is to limit ourselves to providing a working/technical paper (check RAMSAR terminology) that serves as a guide or listing of available and suitable GAPs to improve track one AWIs.

As to the track two guidance, there is a much clearer scope to develop technical content and setting of Good-AWI R&D agenda. A technical paper in this field would then need to cover: (i) existing practices of delimited exploitation of multiple provisioning services – leads to available documentation and gaps to be filled (?); (ii) a critical review and methodology (steps) on the issue of determining replicability of agricultural practices; (iii) identification of ecological domains and hydrological regimes for which Good-AWI practices and techniques can still be developed, and setting of a R&D agenda.

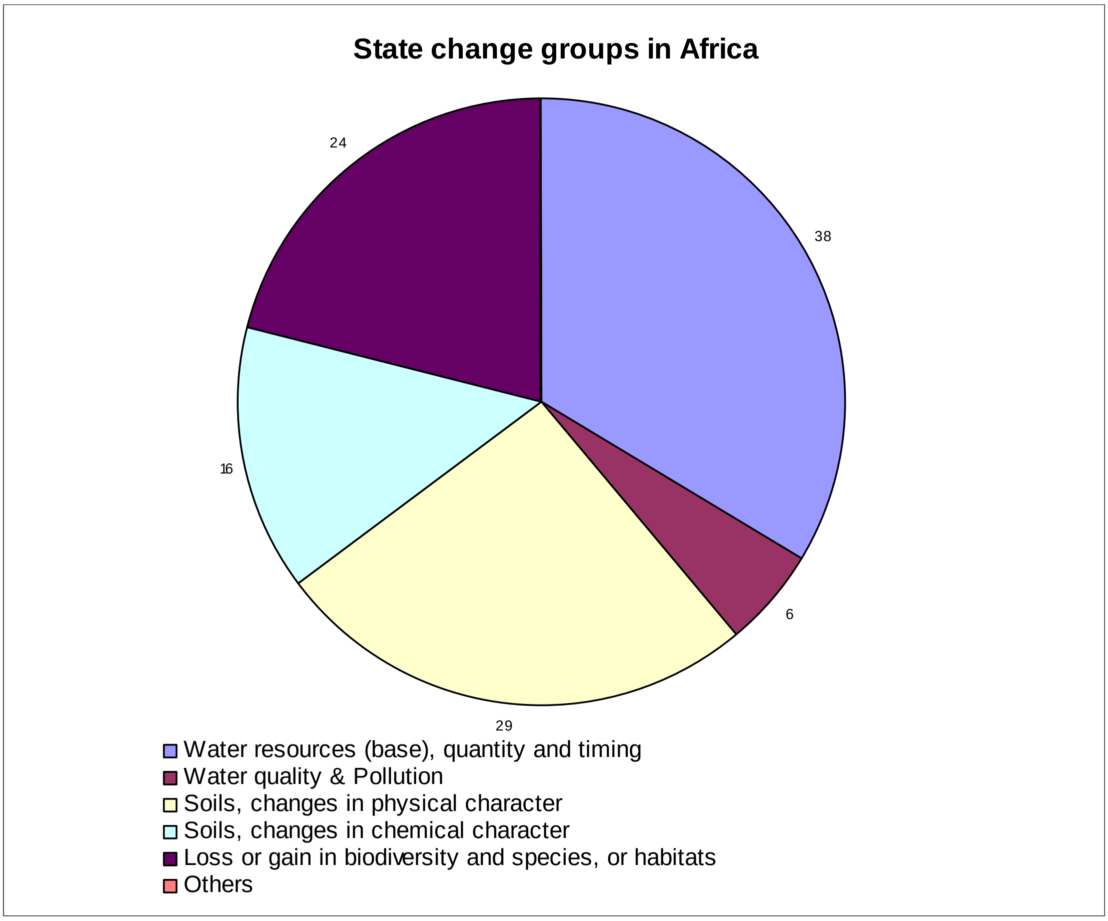
2. Re-dressing State Changes

As indicated in the previous section, the MA ecosystem services framework defines sustainability targets in terms of (re)balancing the multiple services that are derived from, and supported by, the ecosystem. In terms of the GAWI DPSIR framework this balance needs to be achieved at the state level of the ecosystems and resources base. Whereby our definition and analysis of state changes in terms of bio-physical and resource processes is an initial step towards unraveling the interrelationships between services and bio-physical process and sub-entities that constitute the ecosystem (*cf.* footnote 1.) The drivers and pressures can be regarded as further manifestations of (i) the socio-economic purposes & desires to derive specific services from the ecosystem and, (ii) the technological[9] means to exploit these services, respectively. The impacts are subsequently a measure of the benefits, and costs, that obtained by society from the services derived.

In this section a selective set of state changes and their attempted or potential response strategies to re-dress the changes into a more sustainable balance are presented From the data-base analysis in the framework document, two striking general reported state changes are: (i) soil problems in Africa, and (ii) declining fish stocks.

[9] The data-base seems to yield some questionable results with regard to the role of technologies. On the one hand these are listed as not frequently appearing as drivers of state changes, whereas in terms of response strategies applied, a majority is directed towards technical measures at the state level. But this has probably more to do with interpretation and classification than anything else.

Soil problems in Africa:
The issue of soil erosion and its associated problems of sedimentation, soil fertility loss and low yields, is not what we would consider a typical wetland or RAMSAR issue, but definitely a fundamental issue of agriculture. However, as indicated by the data-base, these soil problems clearly interact with, and impact upon, the wetlands. Partly these interactions are bio-physical in terms of increased sediment loads that lead to shifts in hydrological regimes in rivers and wetlands (both in terms of increased runoff peaks and altered water retention and regulation capacity). More significantly though, the associated yield and resources losses will feed negatively back into increased drivers and pressures on rural communities to expand the agricultural 'frontiers' and seek out the often prime land and water resources of wetlands. Which is also reflected in the reported pressures of agricultural expansion, intensification (although this is likely to be strongly driven by markets as well) and water resources management and use once infringing upon wetland water resources.



Thus as part of a comprehensive response strategy it is perfectly obvious and desirable to address this soil root problem within rainfed agriculture. Responses to this issue are, however, agricultural in nature, and consist of establishing Good Agricultural Practices such as Conservation Agriculture that are already part of the R&D agenda of agriculture. However, this does not mean that this issue is therefore easily resolved or implemented. Conservation Agriculture is by far a silver bullet, as an issue specific response strategy on a soil oriented DPSIR analysis remains relevant to address the multitude of drivers and responses that lead to, and continue to sustain, low input and low output erosion prone rainfed agriculture practices. Also, and quite crucially, agronomic hurdles still remain to be taken to adapt the conservation agriculture concept to the agro-ecological specificities and diversity of Africa, as it is based on an agro-ecological cropping system.

A renewed attention and investments to revitalize rainfed agriculture is also entirely in line with the policy recommendations and priorities of the CA, as expressed in policy action 5: *"Upgrade rainfed systems – a little water can go a long way."* This has been clearly identified as the realm of agricultural production in which potentially the biggest gains in productivity can be achieved with regard to agriculture's water and other resources utilization. The CA therefore identifies this as a major field in which productivity advances can and need to be made in order to meet the doubling demand for agricultural production, without excessively depleting the limited water and land resources. (*cf.* CA 2006) However, realization of these gains in rainfed production will in many instances need to be accompanied by investments in supplementary irrigation, especially in light of the predicted increases in rainfall variability (*cf.* IPCC 2007).

Thus, even though conservation agriculture is purely an agricultural response strategy to soil (and water) problems in rainfed agriculture, strategic response alliances between agriculture and wetland sectors in this field are certainly welcome for the enhancement of improved AWI, especially for the indirect basin level ones.

Decline in fish-stocks and fisheries:
The decline in fish-stock and catch is reported as one of the most prominent impacts in the case data-base:

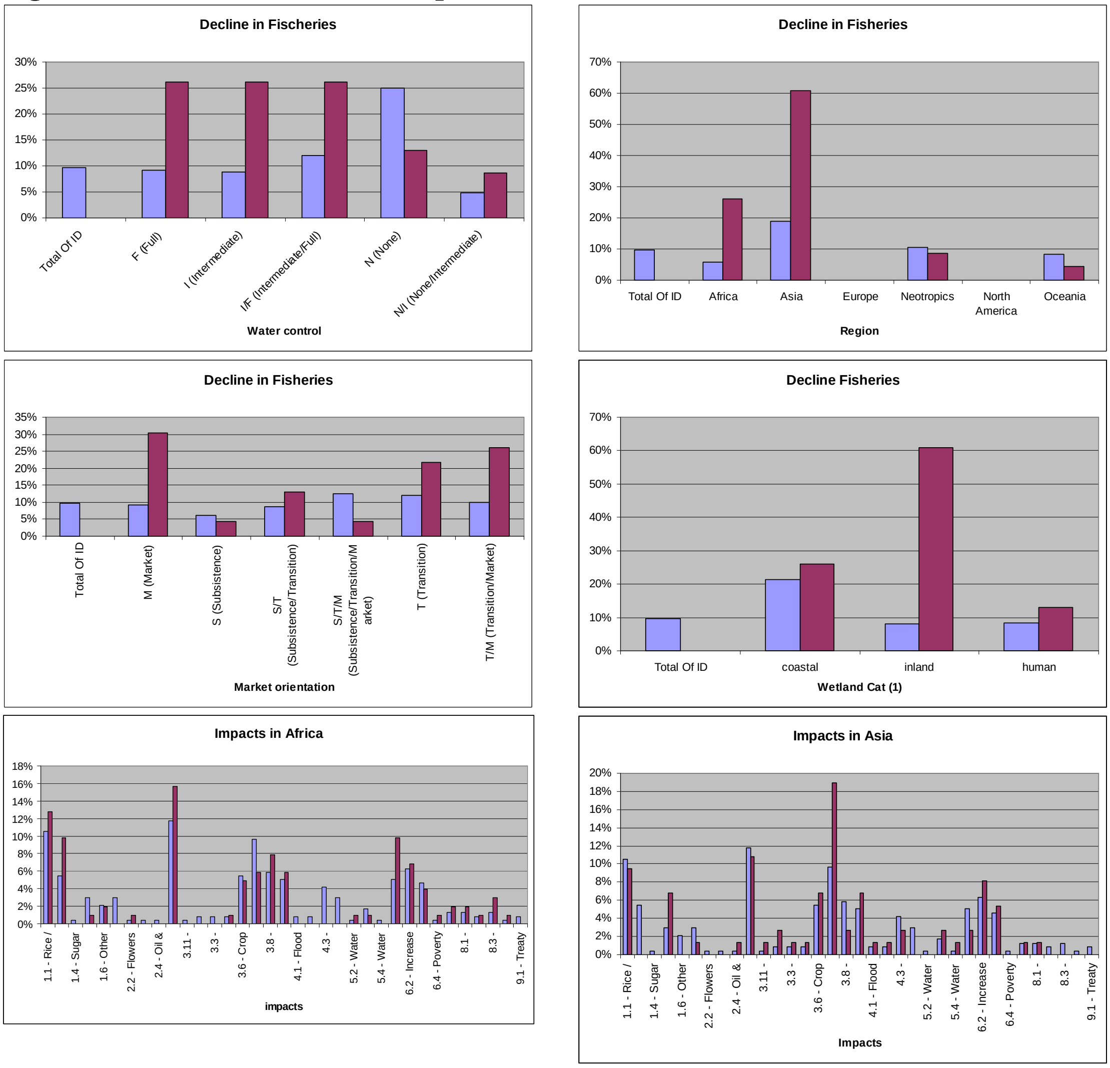
	Impact	As % of total impact*	As % of cases
1	Increase in Crop Production	12	44
2	Increase in cereals	11	40
3	Fisheries (capture) declined	10	37
4	Increase/decrease in conflicts	6	24

* fraction of impact to all reported impacts over all cases, where one case will report more than one impact

As increase in cereals can be subsumed within crop production increases (and thus regarded as double counting) decrease in fisheries assumes a second place in reported impacts. Under conditions of no water control facilities, the impact is more pronounced, constituting 25 per cent of reported impacts under no water control. (Thereby indicating in all likelihood the relative importance of fisheries as a provisioning service under these conditions.) In terms of wetlands, the decline in fisheries is most pronounced in coastal wetlands, amounting to 20 percent of reported impacts. (Most likely for similar reasons.)

Whereas from a regional outlook, the decline in fisheries is the most pronounced in Asia (19 percent) and relatively low in Africa (6 percent). In Africa the impact is less pronounced, as the reported impacts in crop production, decreases in livestock grazing and economic differentiation are relatively more pronounced than the averages reported. Whereas for Asia, the decline in fisheries is clearly the most prominent of all reported impacts. (see figure 4) – However, caution should be taken in that it is not clear in how far the regional results may be skewed by wetland-type (i.e. all coastal wetland case are in Asia).

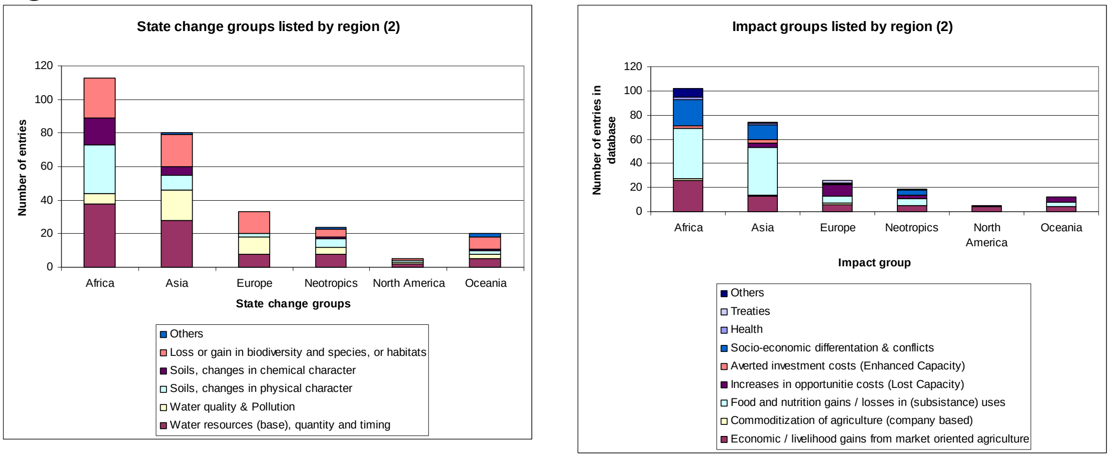
Figure 4: Decline in Fisheries Impact



These reported declines in fish capture are clearly closely associated with alterations in hydrological regimes of rivers and lagoons, and the depletion of stocks and water in confined water bodies and aquatic ecosystems. Which result in negative state changes in river hydrology in terms of degradation of fish habitats for spawning, feeding and (low flow) refuge. (*cf*. Lorenzen et al., 2006) [Note: we have major inconsistency in our data base in that reported decline in fish stock as a state change is a dismal 2 hits – this must be a reporting matter and I suggest to delete the entry.] These usually stem from limited purpose water abstraction and control regime for agriculture and hydropower –

corroborated in our data-base where changes in the water resources base are listed as the most frequent occurring state change (averaging 27 percent), and the associated impact in increased crop production averaging 40 percent (figure 5). However, also positive state changes do occur and are reported, where fish stocks and catches are improved, often purposely, within hydrological and hydraulic infrastructure of the (irrigated) agriculture landscapes (e.g. reservoirs, tanks and canals).[10]

Figure 5

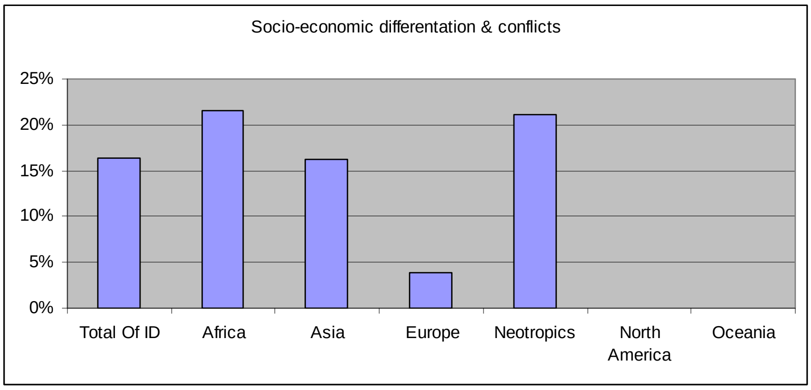


In terms of ecosystem services the decline in fisheries is thus a typical example of the skewed exploitation of services, even within the class of provisioning services, where the over emphasis on crop production leads to the detriment of fish. This also then tends to be reflected in the socio-economic impact, where the skewed exploitation of services leads to socio-economic differentiation (figure 6), as it tend to be the landless, poor and fish-folk that get deprived of their food security and livelihood means to the benefits of farming community. Restoring balances in ecosystem services will in such cases thus also lead to redress of the equity in derivation of economic benefits by different segments of society (i.e. stakeholders and sectors). Whereby success, or ease of achieving success, will largely depend on the degree to which the re-dress of equity depends on re-distribution of benefits from one group to the other (e.g. of economic trade-offs). Which will need to me mitigated primarily at the drivers and pressures level, as illustrated with the cases of the Dutch flood plain policy and Deschutes river conservancy.

But, as Lorenzen et. al. (2006) show and argue, considerable gains in fisheries can already be achieved at relatively low costs to agriculture, by "simply" adopting a multiple purpose hydrological perspective that explicitly accounts for the eco-hydrological requirements of fish stocks. Meeting these requirements can be frequently achieved by introducing alterations in hydraulic structures and targeted modifications in controlled flow regimes. Thereby targeting explicitly for fish water requirements in addition to those for crop production in water management practices.

[10] See for example Lorenzen et. al. (2006), issue chapter 8 with cases of Kirindi Oya, and the restoration of wetlands and lagoons (Chilika).

Figure 6



In terms of the twin-track approach, restoring fisheries would primarily become an issue for establishing and fostering provisioning services in track-II in-situ and periphery exploitations of aquatic ecosystems. Clearly, AWI at basin-level (track-I) will need to be adapted and modified, in particular to remove present inhibits to fish-stock movements. In non closed river basins (*cf.* CA 2006) the opportunities imposed by hydrological functions in the agro-ecological landscape as drainage, water purification, flood protection, and providing low-flow water storage, are potentially suitable to be accommodated in track-II wetland management plans – where the hydrological function is explicitly provided for as a regulating service, and fisheries can be targeted as important provisioning service. In closed river basins (ibid) these options are likely to be restricted to man-made wetlands or reservoirs only.

Socio-ecological systems
Inland fisheries is a typical common resource pool that can easily suffer from the *'tragedy of the commons'* syndrome that leads to over-exploitation of the fish stock and the eventual demise of both fish and fisheries sector. Devising of an adequate management strategy and system that can regulate exploitation and secure the ecological resilience of the stock is therefore essential, and often a challenging task. Different methods and approaches are under development in various fields of common pool resources management (i.e. not only fish), that specifically focus on building institutions for the tasks at hand. Among these, worth mentioning, is the development of "socio-ecological systems" that is specifically geared towards devising management systems based upon monitoring and decision criteria that are derived from the ecological characteristics of the resource in question. (*cf.* Wilson, 2006)
Although not unimportant, it is not recommended for GAWI to enter into this realm of guidance, because: (i) it is not limited and relevant to GAWI issues only; (ii) GAWI has enough on its hands; (iii) there is a lot out there in this field to which reference can be made..

Rice-fish systems and the quest for water productivity

As outlined in issue chapter 10 of the framework document, traditional paddy systems with field to field water supply management are very suitable for fish capture. Whereby the maximization of fish capture in general requires adaptations in water scheduling and management, and the use and scheduling of agro-chemicals. These rice-fish systems have thrived primarily in more traditional south-east Asian paddy landscapes, that are regarded by RAMSAR as man-made wetlands with significant values and services if food production, biodiversity and cultural value – and rightly so.

Within the agriculture and water management sector, the cultivation of paddy has long been regarded as a high water consuming practice. With the current emphasis on coping with water scarcity and the need to *increase the agricultural productivity of water* (*cf.* CA 2006, policy action four), devising agronomic practices that reduce the water requirements of rice cultivation has received a lot of R&D attention. Resulting in new techniques as alternate wet dry irrigation and direct seeded saturated cultivation. Although it can be, and is, debated on what scale of analysis (e.g. field, scheme or river basin) one should consider the efficiency of water use in rice, it should be noted that these new agronomic practices for increased water productivity of rice production do not allow for the exploitation of rice-fish systems within rice field boundaries. In these systems fish need to be relocated to reservoirs, canals and rivers.

Traditional paddy landscapes with multiple services as rice, fish, homestead cultivation and culture, as well as rich agro-biodiversity, that can be considered as man-made ‘cultural’ wetlands, are thus to be regarded as track-II type wetland with strong provisioning and cultural services.

Fisheries guidance

The work initiated by Lorenzen et. al. (2006) in providing guidance in combining irrigation and fisheries through multiple water management services fits perfectly with the GAWI initiative and interests of RAMSAR. Further strategic collaborations in this area thus welcome.

An area that may require further attention in the future is how fisheries can be actively supported as an effective provisioning service within and along different hydrological characteristics of wetlands in the water management landscape.

Flood protection:
The case of the Dutch flood plain policy annotated in its DPSIR elements in chapter two of the framework document provides an excellent example of the principle outlined in section one of basing the management of, in this case, the flood plains around a specific and purposeful hydrological function, namely protection against flooding. Which in the case of the Netherlands represented a marked turnabout with the floodplain land use strategies of the past decades. The basic principle underlying this marked turnabout to base the land and resources use planning of the Dutch river floodplains principally on a regulating service as flood protection, instead of provisioning services as agriculture and urbanization as here to forth, was the Netherlands Government's financial interest in averted investment costs. The extreme river peak flows of the spring of 1995 which lead to serious risks of flooding in Wagenigen and polders to south, some of which were even completely evacuated, brought to the front the serious limitations of the river dikes. The first and immediate reaction to this crisis was that the river dike system was in dire need of a complete overhaul (i.e. stronger and higher dikes). In which it was argued that the lapses to the river dike system had been allowed to creep in, as all the attention and (financial) effort of the sector was directed towards providing a revamped flood protection against the see after the flood of 1953. With strengthening works underway on the weakest river dike sections and as the national overhaul plans started to emerge, it quickly became apparent the government was facing major investments costs for decades to come – just as with the delta-works against the sea that were nearing their completion.

Within the agricultural sector the revision of the EU-CAP system started to play up around this time, with the aim of limiting the overproduction within the agricultural sector. Where the EU production policies had earlier stimulated pressures as colonization, polders and intensification, the reduction of over production was being translated into drivers and pressures to reduce and consolidate the agricultural sector. For non-intensified agriculture attention shifted more towards the multifunctionality of agriculture in becoming managers of the landscape and keepers of rural and environmental patrimony.

The emergence of the new Dutch floodplain policy was the fruit of pairing the turnabout in agricultural policies with the need to provide for an increased flood protection by means of restoring the river flood plains and increase the peak flow capacity within the outer (or winter) dikes. Something that could be relatively easily and cheaply (when compared to revamping of dike infrastructure) achieved by actively restoring the flood plains through hydrological landscaping, limiting and relocating agriculture to non flood intrusive agricultural practices (i.e. low flow summer agriculture). In addition, the new floodplains were ideal to restore wetlands, with which the increasing demands for nature and recreation in Dutch society could be met.

So both from an agriculture interest and flood protection interest, the reshaping of the floodplains could be initiated, and affected farmers compensated to change their practices to flood friendly agriculture (both from agricultural policy reforms and averted flood protection investment costs).

The use of financial compensation measures to effectively transform (or delimit) agricultural practices to subdue to a primary hydrological function as flood protection, will of course not be feasible everywhere outside the OECD. In these circumstances there is thus a clear need to provide for effective alternatives in deriving economic benefits from provisioning and cultural services that are subdued to those of establishing the hydrological service in question. Inevitably, these will need to come from 'Good AWI" practices for track-II type wetlands. To provide for guidance in these, there is thus a need (as described in section one) to: (i) provide an overview inventory or existing provisioning practices and techniques that are suited for track-II type GAWI, classified according to suitability of hydrological function to establish [Do we have any base-work to build upon?]; (ii) setting of a R&D agenda for improving productivity of track-II provisioning services; (iii) provide for methodological guidance for dealing with the issue of ecological replicability of Good AWI.

Even though alternative agricultural practices may improve the relative benefits of "subdued" agriculture, it will be recommendable to transform the multifunctional elements of resources use and management into concrete PES[11], that provide for additional financial benefits (or compensation) to stakeholders to sustain the hydrological and ecological character of the wetland. If not only, to provide some economic insulation against market forces to push provisioning services beyond the boundaries imposed by the eco-hydrological function.

Purification

Environmental degradation as a result of release or production of physical, chemical and/or biological compounds can be caused by a huge variety of human activities, whereas human activities or economic sectors are often associated with characteristic pollutants. E.g. agriculture is mostly associated with nutrients, pesticides and increased salinity. In the mining industry increased concentrations of heavy metals, sulphate and acidy are often experienced. Industries have often very specific effluents, depending on the industrial processes, e.g the leather industry produces chromium, sulphur and various greasy compounds.

Water purification is a very widely applied water management function of wetlands. Wetlands can remove or immobilize a wide variety of physical, chemical and/or biological compounds. As the purification function of wetlands depends on many parameters that need to be controlled and managed, most examples where wetlands are specifically dedicated and managed for purification refer to artificial (constructed) wetlands and remodeled or reconstructed existing wetlands.

Wetlands have a great potential to control and mitigate the impacts of agriculture on surface water resources, as their construction and operation is often cheap in comparison with other remediation options. An example are the wetlands in Southern Florida, USA, where phosphorus removal by artificial wetlands is an integral part of environmental protection and restoration programme. Nearly 20,000 hectares of artificial wetlands were

[11] Whether administered by public or private sector (*cf* UNECE, 2007)

created for storm water treatment. They are often constructed on former agricultural lands to reduce the phosphorous loads that are being discharged by drainage waters. Hence part of the lands were reallocated to provide purification services instead of services to agriculture. At the same time these wetlands facilitate agriculture, as their mitigating function can (in principle) result in less restrictions or less costly measures for agriculture, hence a larger net benefit from the entire area..

The South Florida Water Management District is involved in the construction and management of treatment wetlands in the Okeechobee basin. Lake Okeechobee functions as the central part of a large interconnected aquatic ecosystem and is also the major surface water body of the Central and Southern Florida Flood Control Project and South Florida's most valuable fresh water resource. In addition the lake is important for a number of economic functions, such as water supply (domestic and agriculture) and fishery.

The artificial wetlands were constructed to serve as storm water treatment areas, principally aimed at the restoration of the (downstream) natural wetlands. Nutrient-rich storm water is directed from natural streams to the artificial wetlands and thereafter discharged to the streams again. These wetlands are part of the integrated basin management, which also incorporates BMP for agriculture. Additional retention ponds were constructed on private lands, mostly to restore isolated natural wetlands.

The phosphorus removal occurs by vegetation uptake and soil absorption. The wetlands still have additional hydrological functions, principally water retention.

Also in Florida macrophyte systems for the removal of phosphorus from wastewaters and surface runoff is already investigated and practiced for decades. They are cost-effective and generate good results. The systems also provide storage, which can accommodate agricultural drainage water in order to prevent these from polluting pristine surface waters. Presently various alternative systems are operational, including forested wetlands and managed floating plant systems (periodically harvested). The waters that are treated can be domestic effluents, agricultural runoff and drainage water and eutrophic lake waters.

Another wetland system is created for the removal of phosphorous from the hypertrophic Lake Apopka. Here a 21-km^2 wetland has been constructed where the lake water is recirculated. The costs of this phosphorous removal process is only a fraction of traditional mechanical removal (dredging).

Design and management aspects

The purification function of wetlands can be associated with a wide variety of physical, chemical and biological processes. In order to specifically use wetlands for water purification it is, therefore imperative:

1. Clear specification of the physical, chemical and/or biological compounds that should (principally) be targeted for removal.
2. Selection and good understanding of the (physical, chemical and/or biological) processes that are to be benefited for the removal of pollutants.

Both aspects determine to a large extent the design or remodeling of wetlands, their operation and maintenance, and the opportunities and restrictions to economic functions.

Processes to remove pollutants
The following pollutant removal processes can be distinguished:
- Physical processes: precipitation (e.g. silt removal through settling) and filtration
- Chemical reactions (equilibrium, redox, volatilization, precipitation, biological degradation)
- Adsorption (e.g. removal of phosphor, heavy metals)
- Use by vegetation or degradation by micro-organisms (e.g. nutrients)
- Denitrification[12] (removal of nitrogen)

Certain pollutants may be removed by various processes, e.g. phosphorous can be removed through adsorption to the soil, by plant uptake and by filtration. Plants can either use or adsorb pollutants. The occurring processes obviously have implications for the required management and use potential of the wetlands: Flows may need to be regulated and adsorbed pollutants may periodically need to be removed.

Management
The effectiveness of wetlands for purification is dependent of the wetland type and environmental factors (including the hydrology). The purification processes are often subject to annual or seasonal environmental fluctuations: Water levels, temperatures and light (penetration) affect chemical processes. Most purification processes are rather sensitive to the physical environment. Wetlands with a purification function, therefore, require stricter management and control than, for example, wetlands that principally render water regulation services. As a consequence most situations where wetlands are used for purification refer to artificially constructed wetlands (see also box).

Management implications of processes

Precipitation and filtration
If compounds are to be removed by settling the inflow and outflow velocities are obviously important parameters, which imposes control of the water inflows and outflows. Also the wetland plant species determine the flow velocities and effectiveness of precipitation.

If precipitation occurs through infiltration or recirculation the soil parameters (hydraulic conductivity) are important. As wetlands are, generally, subject to clogging regular

[12] Here mentioned as a separate process given its importance

maintenance is required (silt removal, dredging). This especially applies to natural wetlands, artificial wetlands can be more easily optimized.

Chemical reactions
If compounds are to be removed by chemical reactions the wetlands water composition and oxygen status (and supply) are important parameters. The wetlands chemical composition should obviously be different from the water to be purified. This implies that there should be an additional inflow, which therefore imposes strict control of the fluxes. The oxygen status is dependent on the interaction with air (diffusion at the surface, mostly through turbulence) and underwater plant photosynthesis.

Adsorption
If compounds are to be removed by adsorption the geometry of the wetland (depth, area surface, shape of the bottom) are determining factors. These require minimum management. The type and composition of soils or substrates and the vegetation are also critical parameters, as well as the flow velocities.

Use by vegetation
If compounds are to be removed by vegetation uptake the vegetation and flow velocities are the determining factors.

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