A Smallgrower's Challenge to 'Emerge'

Exploring the diversity of evapotranspiration, biomass, yield production and crop water productivity of sugar cane in the Lower Komati sub-catchment, South Africa

M.Sc. Thesis by G.M. ten Napel

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Master thesis Irrigation and Water Engineering submitted in partial fulfillment of the degree of Master of Science in International Land and Water Management at Wageningen University, the Netherlands

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ABSTRACT

The Inkomati catchment is one of 19 Water Management Areas (WMAs) in South Africa bordering Mozambique and Swaziland. Within the Inkomati WMA, the Lower Komati sub-catchment is an area of intensive sugarcane farming. Historically, the area was reserved for large scale ‘white’ commercial farming, but since Apartheid came to an end in 1994, the South African government is aiming to redress the racial and gender inequities of the past. In 1994, the Nkomazi Irrigation Expansion Programme (NIEP) was started with the objective to promote economic development for the ‘black’ people in the area. 9,800ha of previously under utilized land was transformed into 1500 irrigated sugarcane farming ventures. It was assumed that sugarcane would help these farmers emerge as commercial producers, transforming their farming systems into those associated with commercial production. In this research, the parameters of ET_a, biomass, yield production and crop water productivity are used as indicators for the socio-economic objectives of the NIEP. The diversity of these four parameters among both commercial and emerging farmers in the Lower Komati is quantified using satellite imagery and remote sensing. In order to explore the transition process of the NIEP, reasons for the diversity in ET_a, biomass, yield production and crop water productivity are sought among crop-physiological factors such as climate and clay content of the soil, but also among socio-economic factors such as water quantity and soil fertility. Final reasons for this diversity are explored within the concept of the farming system.

KEYWORDS: LOWER KOMATI, EMERGING FARMERS, COMMERCIAL FARMERS, EVAPO-TRANSPIRATION, BIOMASS, YIELD PRODUCTION, CROP WATER PRODUCTIVITY, FARMING SYSTEM

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SUMMARY

This thesis attempts to bring social and technical components related to actual evapotranspiration (ET_a), biomass, yield production and crop water productivity (CWP) together. Using satellite imagery, remote sensing and the SEBAL model, the variation in ET_a, biomass, yield production and CWP in the Lower Komati sub-catchment was pre-assessed. This variation was then explored further by combining the technical pre-assessment with socio-technical research in South Africa. This socio-technical part included technical yield measurements by TSB Sugar, as well as farmer questionnaires, farmer group discussions, interviews with relevant stakeholders and field visits.

The first chapter starts with giving an overview of the research area and introducing the stakeholders. It then presents the problem description and the objectives of this research. The problem definition and objectives set the base for the conceptual framework that will be discussed in chapter 2. The conceptual framework in chapter 2 sets out the structure of this report, and together with the problem definition it leads to a formulation of the research questions and methodology.

Chapter 3 starts with giving a visual overview of the distribution of ET_a, biomass, yield production and CWP of sugarcane plots in the Lower Komati. In order to explain the reasons for this diversity among commercial and emerging farmers, the effects of three crop-physiological factors (climate, clay content of the soil, and crop variety) on these four parameters are explored. It is established that the effect of soil class on ET_a, biomass, yield production and CWP is larger than the effect of climate. The effect of crop variety cannot be established clearly as yield production is influenced by other factors such as the application of fertilizers and weed control. Besides these three crop-physiological factors, water quantity is explored in a socio-economic way. The manageable factors of water allocations, irrigation types and irrigation design prove to influence the variety in ET_a, biomass, yield production and CWP further and are described qualitatively.

Chapter 4 gives an insight into the two main farming systems of the Lower Komati, and shows the way in which emerging farmers have been influenced by the Nkomazi Irrigation Expansion Programme (NIEP). In chapter 4, different farming typologies are established based on the physical characteristics of sugarcane plots as described in chapter 3. Looking at yield production in particular, it is concluded that all farming typologies consist of both optimal and sub-optimal farmers. Reasons for these differences in yield production are sought within the farming typologies of the farmers and are either related to internal or external factors. These different typologies set standards for farmers to improve their water, fertilizer and crop management. Factors within these farming typologies include the socio-economic aspect of soil fertility (fertilizers), as well as aspects related to crop management, skills, labour, commitment and finances. Finally, chapter 5 will present the conclusion of this thesis, as well as a discussion and recommendations for further research.

LIST OF ABBREVIATIONS

ACER	Agricultural, Community, Environmental and Rural Development Consultants
BE	Black Empowerment
CASP	Comprehensive Agricultural Support Programme
CDA	Cane Delivery Agreement
CF	Commercial Farmer(s)
CLP	Compulsory Licensing Process
CMA	Catchment Management Agency
CWP	Crop Water Productivity
DALA	Department of Agriculture and Land Affairs
DBSA	Development Bank of South Africa
DFID	Department for International Development
DoA	Department of Agriculture
DWAF	Department of Water Affairs and Forestry
EF	Emerging Farmer(s)
ERC	Estimated Recoverable Crystal
ET	Evapotranspiration
ET_a	Actual Evapotranspiration
ET_c	Crop Evapotranspiration
ET_o	Reference Evapotranspiration
FAF	Financial Aid Fund
GDP	Gross Domestic Product
GIS	Geographical Information Systems
GWCA	Government Water Control Area
HDI	Historically Disadvantaged Indivual(s)
IB	Irrigation Board
ICMA	Inkomati Catchment Management Agency
K	Potassium
KOBWA	Komati Basin Water Authority
KRIB	Komati River Irrigation Board
LIB	Lomati (River) Irrigation Board
LRAD	Land Distribution for Agricultural Development
MADC	Mpumalanga Agricultural Development Corporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MBB	Murray Biesenbach & Badenhorst Consulting Engineers
N	Nitrogen
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NIEP	Nkomazi Irrigation Expansion Programme
NOWAC	Nkomazi/Onderberg Water Action Committee
NWA	National Water Act
NWRS	National Water Resource Strategy
P	Phosphorus
RSA	Republic of South Africa
RTO	Right to Occupy
RV	Recoverable Value
SASA	South African Sugar Association
SASEX	Research Sugar Experiment Station
SASMA	South African Sugar Miller's Association
SASRI	South African Sugar Research Institute
SEBAL	Surface Energy Balance Algorithm for Land
TCU	Total Consumptive Use
TSB	Transvaal Suiker Beperk
WMA	Water Management Agency
WSA	Water Services Act
WUA	Water Users' Association
ZAR	South African Rand (Zuid Afrikaanse Rand) – ZAR 1 ≈ € 0.09 (September 2008)

CHAPTER 1: INTRODUCTION

In 1998, South Africa implemented a new progressive National Water Act (NWA). The country's commitment to the reform of water management and the development of real integrated water management approaches make it interesting for water management research. In Mpumalanga, water management is not only paperwork. The stakes are high and people put a lot of effort in management of the river. The river water is mainly used for agriculture, and is perceived to be scarce and contested. During the Apartheid era, large white farms benefited from a privileged access to natural (water) resources and rural infrastructure. Since Apartheid came to an end in 1994, the South African government is aiming to redress the racial and gender inequities of the past, and the NWA provides the legal framework for the new policy.

The Inkomati catchment is one of the 19 Water Management Areas (WMAs) in South Africa. It is located in north-eastern South Africa and borders Mozambique to the East and Swaziland to the South-East. It is made up of three principle river catchments: the Komati, the Crocodile and the Sabie-Sand. All drain in an easterly direction and eventually flow over the border into Mozambique. Irrigated agriculture is the dominant water user in the Inkomati WMA, accounting for 57% of the total water requirements (DWAF, 2004). The Lower Komati sub-catchment comprises 2,371km^2 around the Komati River (1672km^2) and its major tributary, the Lomati River (699km^2) (Waalewijn, 2002). In 1994, the Nkomazi Irrigation Expansion Programme (NIEP) started a challenge of black empowerment, with the objective to promote the economic development of the Nkomazi region. Its initial aim was to provide funding, support and resources for 960 black farmers spread over an initial 7,200ha. Sugarcane was chosen as a stepping stone out of poverty and as a livelihood strategy for black farmers. It was assumed that sugar would help them emerge as commercial producers, transforming their farming systems to those associated with commercial production. In order to start this agricultural transformation of poor smallholder farmers to commercial farmers, NIEP provided the smallholders with a technological package, including land and water access, technical support and managerial advice. The sugar mill, TSB, was part of the technological package offered by NIEP, as it provided the farmers with many services such as extension, loans, irrigation, transport, logistics and a guaranteed market. However, it is unknown to what extent this agricultural transformation process has been completed in the Lower Komati, and how this has affected the farming systems of the emerging farmers.

This thesis will use the parameters of ET_a, biomass, yield production and CWP as indicators for the socio-economic objectives of the NIEP. In order to explore the transition process of the NIEP, the diversity of these four parameters among commercial and emerging farmers in the Lower Komati will be explored. Firstly, this diversity will be quantified using satellite imagery and remote sensing. Secondly, crop-physiological factors that might influence this diversity will be explored, as well as socio-economic aspects of water quantity. Finally, farming typologies will be classified for both commercial and emerging farmers based on similar physical characteristics. Final reasons for the diversity in ET_a, biomass, yield production and CWP will be explored according to the concept of the farming system. Within each farming typology, the presence of both sub-optimal and optimal farmers will be explored. The focus will be on factors within the different farming typologies, such as water, fertility, and crop management, which indicate possibilities of sub-optimal farmers to become optimal farmers. This first chapter will start with giving an overview of the research area and introducing the stakeholders. It will then present the problem description and the objectives of this research.

1.1 THE CONTEXT: WATER AND LAND REFORM IN SOUTH AFRICA

1.1.1 Water Reform and the National Water Act

South Africa is a water scarce country with a low average annual precipitation of about 450mm per year and a comparatively high evaporation. The climate is semi-arid and varies from desert and semi-desert in the west to sub-humid along the eastern coastal area. The annual per capita water availability of 1099m^3 is just over the level of 1000m^3/capita/year that is considered to indicate the state of water stress (Schoch, 2007). Historically, water rights in South Africa were based on riparian principles, where owners of land were entitled to use rainfall that fell on the land, groundwater under the land, and surface water bordering the land. Water rights thus mirrored the racially skewed nature of land holdings (Waalewijn *et al.*, 2005).

During the Apartheid era, large white farms benefited from a privileged access to natural (water) resources and rural infrastructure. Since Apartheid came to an end in 1994, the South African government is aiming to redress the racial and gender inequities of the past. The 1997 Water Services Act (WSA) and the 1998 National Water Act (NWA) provide the legal framework for the new policy The reforms, which radically change the principles of ownership, access and use of water in South Africa, are internationally regarded as a pioneering attempt to regulate water use in ways that are environmentally sound and socially fair (Brown & Woodhouse, 2004).

The NWA with its slogan “some, for all, forever”, makes an explicit goal to redress the past inequality in water use. Its purpose is “to ensure that the nation’s water resources are protected, used, developed, conserved, managed, and controlled in ways that take into account:

- meeting basic human needs of present and future generations;
- promoting equitable access to water;
- redressing the results of past racial and gender discrimination;
- promoting the efficient, sustainable and beneficial use of water in the public interest;
- facilitating economic and social development;
- providing for growing demand for water use;
- protecting aquatic and associated ecosystems and their biodiversity;
- reducing and preventing pollution and degradation of water resources;
- meeting international obligations;
- promoting dam safety;
- managing floods and droughts.

And, for achieving this purpose, to establish suitable institutions and to ensure that they have appropriate community, racial and gender representation” (Woodhouse, 2008:3).

Under the terms of the NWA, all water in South Africa is to be considered an “indivisible national asset” for which the government’s Department of Water Affairs and Forestry (DWAF) is the custodian in the public interest (DWAF, 2004). Integrated catchment management is to be achieved following the principle of decentralization of water management in each Water Management Area (WMA) to a single Catchment Management Agency (CMA) representing the interests of different water uses at catchment level. The NWA provides that central government (DWAF) may delegate far-reaching powers to the

CMA, phased out over time as and when the CMA is deemed a ‘responsible authority’. The CMA would then effectively take over many of the operational functions currently undertaken by the DWAF regional offices. Within the WMA, water management at local level is to be undertaken by Water User Associations (WUAs) defined as ‘co-operative associations of individual water users who wish to undertake water-related activities for their mutual benefit (Woodhouse, 2008:6-7)’.

1.1.1.1 Remote Sensing and the National Water Act

Government objectives for managing water resources in South Africa are set out in the National Water Resource Strategy (NWRS). Key principles are *sustainability*, *equity* and *productivity* (DWAF, 2004). This paragraph notes the potential contribution of remote sensing, as means to map, spatially and temporally, the evapotranspirative consumption of water and associated biomass formation, to these principles. Remote sensing allows quantitative measurements (spatial and temporal) that provide a national, basin and catchment scale set of data on the state of the hydrological cycle.

Sustainability
Measuring and monitoring trends in evapotranspirative consumption on the scale required to support judgements about sustainability is uniquely feasible through remote sensing means as they offer the potential to monitor thousands of square kilometres in one single image.

Equity
Equity is indicated by the intensity of evapotranspirative use and production at various scales: per hectare, per farm, or per socio-economic group (emerging farmers vs. commercial farmers).

Productivity
Crop water productivity is indicated by the production achieved per unit of evapotranspirative consumption.

When it comes to water resources management as addressed by the act, the impacts of water control and distribution to various evapotranspirative uses (categories of crops, farms and users) can be monitored by remote sensing, both in terms of consumptive use and productivity. It can indicate the potential for improved management where productivity is low, and the identification of good management where productivity is particularly high.

A pattern of water use can include measures of evapotranspiration (ET - how much water the area is consuming through its vegetation and wet areas), and what degree of plant activity is going on (indicators of biomass production). When mapping the pattern of consumptive water use in a given area this could provide a statistical description of the area. This could then provide a set of descriptive data for the relevant area that can be monitored over time as the development of the water resources takes place. This can provide a basis for monitoring whether significant changes in the patterns of ET and biomass are taking place which would be indicators that an “impact” was underway. It could then provide the basis for interventions to suspend or reduce stream flow reducing activities. Remote sensing of this type can provide significant information to facilitate development of catchment management strategies. The data can be assembled relatively quickly, based on uniform analytical procedures that have been internationally tested (Soppe *et al*., 2006).

1.1.2 Land Reform

Land reform in South Africa strongly influences water reform. The state has pursued land reform through four processes. These are: restitution (returning land or providing a cash equivalent) to people dispossessed under apartheid; redistribution (transferring more land to black owners); tenure reform (modernising land tenure rules and access to land ownership); and providing funding and other resources to support the emergence of black farmers. The government's goal of transferring 30% of agricultural land (sometimes stated as commercial (white-owned) farmland) into black ownership was only achieved by 4.3% in the first decade (1994-2004). After that the political pressure was renewed to quicken the pace of land reform, due to continuing high levels of inequality, unemployment and poverty (Bernstein, 2008).

It is believed that 90% of the validated restitution claims had been settled by the end of 2007, mainly because most of the urban claims could be settled with cash payments that did not entail complex negotiations or very large price tags. Many rural claims have also been settled with cash. However, the settlement of the remaining 5000 claims remains a slow process, as these are the most expensive and complex claims (Bernstein, 2008). Land claimants are frustrated by these delays, and sometimes resort to land invasions, while existing farm owners are unable to sell land once it has been claimed. Banks do not accept claimed land as collateral for loans. Some farmers therefore lack the incentives and/or the money to continue working with the land, and it is sometimes taken out of production or allowed to deteriorate.

The process of redistribution (including the LRAD (Land Distribution for Agricultural Development) programme designed to provide grants to black South African citizens to access land specifically for agricultural purposes) has also been slow. Because of budget constraints, and because it seems that the government lacks the skills required to buy land efficiently, only around 4.7% of commercial agricultural land has been redistributed so far. The government's target is 30% by 2014. According to the Department of Land Affairs (DALA), white-owned commercial farmland in South Africa comprises 82 million hectares, meaning that the transfer target is 24.6 million hectares. By November 2007, some 4.2 million hectares had been redistributed. New farmers established through redistribution programmes are unequally distributed by province, with more than 65% being located in Mpumalanga and the Western Cape (Bernstein, 2008). The government has acknowledged that redistribution is proceeding too slowly. As the process is based on a 'willing buyer, willing seller' basis officials often attribute slow progress to high land prices and a lack of willing sellers. However, farmers, who are often willing to sell their land, have indicated that redistribution is often being slowed down by inexperienced officials and poor relationships (CF, 2008[♦]). Stalled restitution is another issue, as this prevents market transactions (including those supported by government redistribution grants) from being concluded.

1.2 THE INKOMATI CATCHMENT

1.2.1 The Inkomati Water Management Area

The Inkomati catchment is one of 19 WMAs in South Africa. This WMA (figure 1.1) is a sub-basin of the transboundary Inkomati River Basin which covers 46,800km^2 and is shared by South Africa (61%), Swaziland (5%) and Mozambique (32%). The Inkomati WMA is located

[♦] Refers to personal communication with Commercial Farmers (CF).

in north-eastern South Africa and borders Mozambique to the East and Swaziland to the South-East. Administratively, the majority of the Inkomati WMA falls within Mpumalanga Province, with a portion within the Northern Province (also known as Limpopo). Three principle river catchments make up the Inkomati WMA: the Komati, the Crocodile and the Sabie-Sand. All drain in an easterly direction and eventually flow over the border into Mozambique. The Great Escarpment, which divides the WMA into the Highveld plateau area in the west (2,000m.a.s.l.) and the Lowveld to the east (140m.a.s.l.), is the most striking topographical feature of the Inkomati WMA (Waalewijn *et al.*, 2005). Rainfall, which is strongly seasonal occurs mainly in the summer months and ranges from 400mm to 1,000mm over most of the Lowveld through to 1,500mm in mountainous reaches of the escarpment. Annual evaporation rates vary across the WMA, from less than 1,400mm in the Highveld to more than 1,900mm in the Lowveld. Almost all the mean annual runoff in the basin is generated in the upper parts of the three sub-basins (Brown & Woodhouse, 2004). Although quantitative data on water use are contested, the general picture is one of a closing basin with some particularly stressed sub-basins.

Irrigated agriculture is the dominant water user in the Inkomati WMA, accounting for 57% of the total water use (DWAF, 2004). Within the individual catchments, with the exception of the Komati West of Swaziland, irrigation also has the largest water requirement: 73% in the Komati North of Swaziland, 62% in the Crocodile and 50% in the Sabie/Sand catchment (see table 1.1). More recent estimates claim that demand for water for irrigation must be as high as 83% of all water demand in the WMA, and that the total demand is approximately double the water available in the catchment (Water for Africa, 2006, as cited in Woodhouse, 2008).

Catchments	Komati (West of Swaziland)	Komati (North of Swaziland)	Crocodile	Sabie/Sand	**Total Inkomati WMA**	%
Irrigation	21	222	257	65	565	57.0
Urban	2	3	35	22	62	6.3
Rural	4	6	7	4	21	2.1
Mining	-	1	23	0	24	2.4
Afforestation	23	12	42	37	114	11.5
Total Requirements	**50**	**244**	**364**	**128**	**542**	
International Requirements	-	60	49	0	109	11.0
Transfers	97	-	0	0	97	9.8
Grand Total	**147**	**304**	**413**	**128**	**992**	

Table 1.1: Water use (million m^3/annum) for the various water users in the Inkomati WMA for the year 2003 (DWAF, 2004).

Topography and climate have resulted in three basic irrigation zones. In the Highveld (Komati West of Swaziland and the Upper Crocodile catchment) where rainfall is higher, fodder and vegetable crops are grown. In the Middleveld (Sabie and Central Crocodile) irrigation is used for tropical and sub-tropical fruit. In the Lowveld (Komati North of Swaziland and Lower Crocodile, together known as ‘Nkomazi’) sugarcane predominates along with some citrus and tropical fruits. The geography of irrigated agriculture still largely reflects its development under the Apartheid era, almost entirely in white farming areas. Two TSB (Transvaal Suiker Beperk) mills, together with a Sappi Kraft paper mill, are the main industrial users of water in the Inkomati WMA (Brown & Woodhouse, 2004). TSB has a potentially powerful position in the Inkomati CMA as sugar accounts for over a third of the land irrigated in the WMA.

1.2.2 The Nkomazi

The Nkomazi area is roughly an equilateral triangle of 323,672 ha (DALA, 2005) that includes the Lower Komati sub-catchment (Komati North of Swaziland) largely corresponding to the former homeland area of Ka Ngwane, and the lower Crocodile sub-catchment (Onderberg), an area of large scale white commercial farming. The total irrigated area (60,530 ha) is dominated by sugarcane (40,453 ha (TSB, 2007)) which supplies 20% of South Africa's total sugarcane (SASA, 2008a). Other irrigated crops are bananas (4,300 ha), citrus (4,000 ha), lychees (380 ha), mangoes (1,150 ha), papayas (700 ha) and vegetables (500 ha) (A. Van Der Merwe, 2008).

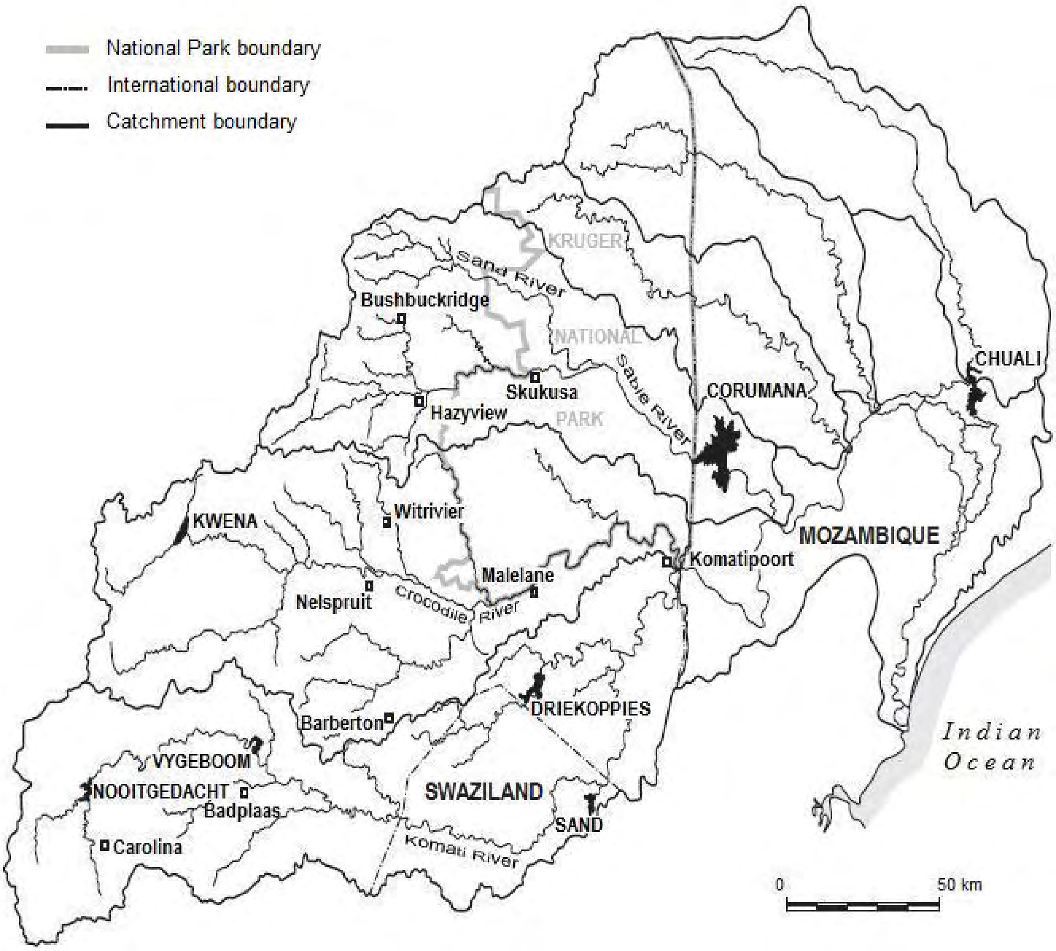


Figure 1.1: The Inkomati WMA (Brown & Woodhouse, 2004).

The Nkomazi region is the only region in South Africa where sugarcane is intensively irrigated. Sugar yields are higher on average than in the rest of the country (SASA, 2008a). The cane is processed in two sugar mills, one at Malelane (1965) and one South of Komatipoort, which was built in 1997 to allow for expansion of the sugar area. Both mills are owned by TSB Sugar. As the sole purchaser of sugarcane, TSB is an important stakeholder within the Nkomazi area, wielding considerable power over its growers and the Irrigation Boards (IBs).

1.2.2.1 The Nkomazi Irrigation Expansion Programme

The Nkomazi Irrigation Expansion Programme (NIEP) was initiated under the Ka Ngwane administration to promote small scale sugar farming by black farmers, thus generating employment and skill development for communities in this area of high unemployment (Brown & Woodhouse, 2004). Its objective was "to promote the economic development of the Nkomazi Region of Mpumalanga Province using agricultural development as catalyst, vehicle and driving force" (Waalewijn, 2002) with its main purpose being to provide funding, support and resources to assist in the establishment of 19 irrigation projects, and to support 960 emerging farmers spread over 7,200 ha of land (Anderson, 2001). It provided for the development of irrigation schemes with an average size of 250 ha, with a central pump station, common mainlines, and drag-line sprinklers for field irrigation. The average farm size decreased from 20 ha/capita for the first schemes to 7 ha/capita in the last schemes (Waalewijn *et al*., 2005).

Sugar was chosen over other crops by the planners: "It is an excellent crop for emerging farmers" as it is easy for inexperienced growers to manage: it can be harvested in the first season, unlike tree crops. Furthermore, the TSB mills guarantee a local market, providing a dependable income that makes sugar the preferred option for black emerging farmers, despite higher likely returns on alternative crops and the risk of dependency associated with a sugar monoculture. It was claimed that through sugar cultivation, emerging farmers would acquire transferable managerial and marketing expertise giving them the option to diversify later (Brown & Woodhouse, 2004). However, diversification can only happen when risk-factors associated with other crops, such as vegetables and sub-tropical fruits, are reduced to levels closer to those associated with sugar. Moreover, it is essential that the smallholder growers are truly provided with adequate technical and managerial skills, and not just with simply a share of the profits from a large production system (Woodhouse & Hassan, 1999). True diversification can be problematic. Anderson (2001) notes that many emerging farmers lack skills for diversification and that the technical skills offered by TSB are not so forthcoming in establishing other more technically demanding crops such as vegetable or fruit orchards.

Still, at national scale NIEP is regarded as one of the most successful rural development programs. There are several reasons for the relative success of the program, such as the presence of a local and easy market for the crops and the favourable climatic conditions. The first phase of NIEP (1993-1998) had 7,094 ha of sugarcane planted (NOWAC, 1999). During this first phase, which was funded by the Development Bank of South Africa (DBSA), many farmers encountered managerial problems, as the process was rather top-down. The designs were mainly based on technical considerations, and little consideration was given to institutional support for the farmers (Waalewijn, 2002). The second phase started in 2000 and resulted in another 15 projects and 2700ha. The last seven projects were funded by Land Bank. NIEP has created many jobs in the area. It is still true, however, that many people are still unemployed and the situation might have worsened in other sectors than agriculture.

1.3 THE RESEARCH AREA: THE LOWER KOMATI

1.3.1 The Komati Sub-Catchment

One of the three sub-catchments of the Inkomati WMA is the Komati sub-catchment. The catchment area of the Komati River and its tributaries is 11,210km^2 of which 2,560km^2 of the middle stretch fall within Swaziland (see figure 1.2). Irrigation is by far the largest water user in the sub-basin (58% Total Consumptive Use (TCU)) especially in the Lower Komati where it accounts for 93% of TCU (see table 1.2) (MMB *et al.*, 2000).

Figure 1.2: The Komati Sub-Catchment (MMB *et al.*, 2000).

	Komati			Lomati				
	Upper	Swazi	Lower	Upper	Swazi	Lower	Total	% TCU
Area (km²)	6,049	1,995	1,672	228	566	699	11,209	
MAR generated locally	703	360	44	77	149	87	1420	
Water use by sectors								
Forestry	63.7	24.6	0	13.7	21.4	21.6	145.0	16.8
Primary and Industrial	138.2	10.6	5.4	0	1.0	3.6	158.7	18.3
Irrigation	26.5	170.9	211.4	0	5.1	86.2	500.1	57.8
Game and Livestock	2.2	1.5	1.0	0.1	0.4	0.3	5.6	0.6
Riparian Vegetation	23.1	11.6	9.7	1.5	3.9	6.3	56.1	6.5
Total consumptive use	**253.7**	**219.2**	**227.5**	**15.3**	**31.8**	**118**	**865.5**	**100.0**
TCU / MAR generated locally (%)	36	61	517	20	21	136		
TCU / total MAR (%)	**18**	**15**	**16**	**1**	**2**	**8**	**60**	

Table 1.2: Mean Annual Runoff (MAR) and consumptive water use Komati Sub-Basin (Mm^3/y) (MMB *et al.*, 2000).

1.3.2 The Lower Komati

The Lower Komati sub-basin is the focus of this research. It is part of the Nkomazi area, and comprises 2,371km² around the Komati River (1672km²) and its major tributary, the Lomati River (699km²). These two rivers have a combined length of some 200km, and there are some smaller rivers contributing to these rivers in the lower reaches: the Mzinti, the Mkwakwa, and the Mlambayati (Waalewijn, 2002). The Lower Komati is defined as the stretch of land from the Swaziland border to the confluence of the Komati River and the Crocodile River at the border with Mozambique. It is considered to be one of the most fertile agriculture regions of South Africa.

1.3.2.1 Climate

The climate in the Lower Komati is hot and humid, it being the warmest humid place of South Africa. Average temperatures range between 22°C and 35°C. In Komatipoort, summer temperatures can reach 45°C (SASRI, 2008a). Rainfall (mean 650mm/a) is erratic (Waalewijn, 2002) and 80 to 85% of the rain falls from October to March. The climatic conditions enable the growth of many (sub) tropical fruits and give the area a high agricultural potential.

Except for the surrounding mountains, the region is characterized by flat to gently undulating topography. Due to effects of these surrounding mountains, temperatures in the sub-basin may change a couple of degrees from region to region. Similarly, the amount of rainfall also changes from region to region. Figures 1.3 and 1.4 illustrate this.

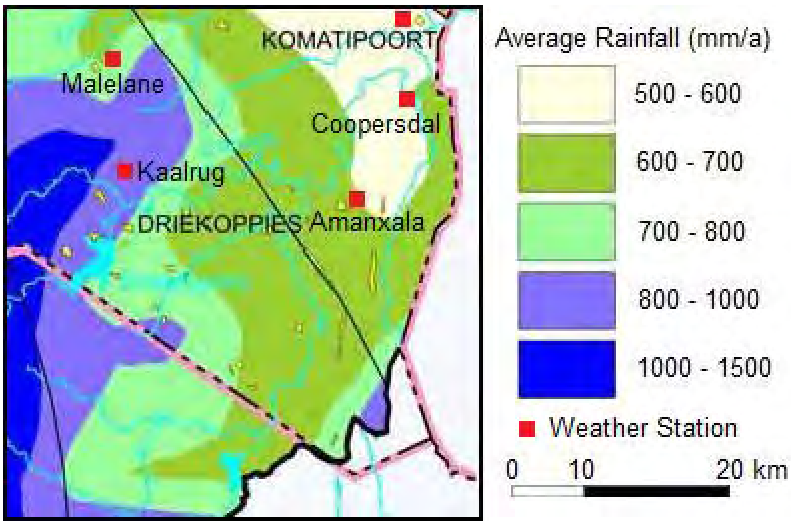


Figure 1.3: Average rainfall and weather stations in the Lower Komati (DWAF, 2000).

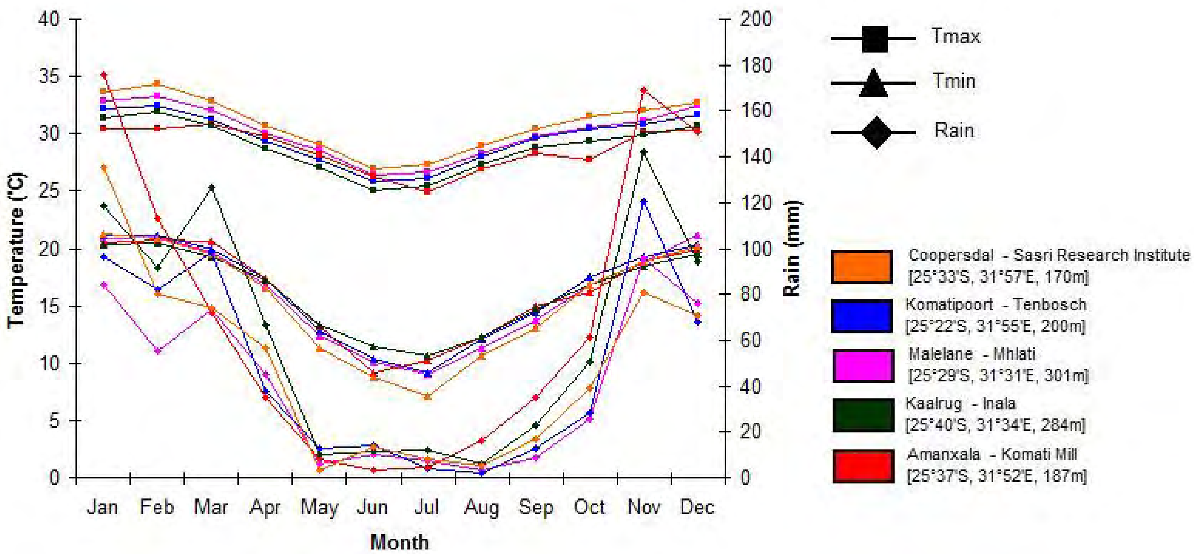


Figure 1.4: Long term maximum temperature, minimum temperature and rainfall for the five weather stations in the Lower Komati (SASRI, 2008a).

1.3.2.2 Water Resources

In 1998 South Africa completed Driekoppies Dam (251Mm^3) on the Lomati River, which was one of two dams being constructed under the bilateral agreement between Swaziland and South Africa. In 2002 another dam was commissioned on the Komati River in Swaziland: Maguga Nkomati Basin dam (332Mm^3) (Carmo Vaz & Van Der Zaag, 2002). Driekoppies Dam was filled up in 2000 due to excessive rainfall which also resulted in major flooding. However, when a severe drought started in 2002 this resulted in severe water restrictions for both countries. As a result of the continuing drought situation, some of the existing irrigated areas were withdrawn from production. During the year 2006/2007 above normal rainfall and stream flow was recorded in the Komati River system, and this finally alleviated the drought. As a result Maguga Dam spilled for the first time since its completion, while Driekoppies Dam spilled for the second time. Due to the improved water situation full water allocations could be allocated again (KOBWA, 2007). Table 1.3 shows the total water use of the Komati River system as estimated by the Komati Basin Water Authority (KOBWA) for 2006/2007.

WATER USE DOWNSTREAM OF DRIEKOPPIES DAM AND MANAGA IN SOUTH AFRICA March 2007		
	AMOUNT Mm^3	BALANCE Mm^3
Water use from Driekoppies Dam Add flow across Mananga Border	126.7 357.3	
Subtract releases for Mozambique	235.6	484.0
Subtract riverine losses	33.6	248.5
Subtract domestic and industrial use	18.2	214.3
Add gross accruals from: Driekoppies to Lebombo Mananga to Tonga	 31.3 36.1	196.7
Add water used from storage in the weirs (assumed)	0.0	264.1
Irrigation water use in 2006/2007*		264.1
* Remaining irrigation water downstream of Mananga and Driekoppies Dam on March 31		
- South Africa (system not full)	=	21.3 Mm^3
Actual booked irrigation use in 2006/2007	=	264.1** Mm^3
** Expected use which is	=	310.8 Mm^3

Table 1.3: Water use statement for the water year 2006/2007 (KOBWA, 2007).

In the Komati River 18 weirs were built with a total capacity of 19Mm^3 (MMB *et al.*, 2000). The weirs in the commercial area were built by settlers to retain excess water and to have stable water levels for the operation of pumps. These were paid for, owned and operated by the farmers' community as organized by the IB (Waalewijn, 2002). The weirs in the smallholder projects were funded by the government and built after 1993 as part of the NIEP. The floods of 2000 destroyed all the weirs. While the weirs of the emerging farmers were never repaired, the commercial farmers organized themselves and rebuilt seven of them (CF, 2008[♦]). The Lomati River has one privately constructed weir which is used for power generation.

For the whole catchment the total net potential contribution by groundwater is estimated to be about 5Mm^3/annum (MBB *et al.*, 2000), and the total recoverable quantity about 11Mm^3/annum (DWAF, 1997, as cited in Waalewijn, 2002). Groundwater does not play an important role in the region, but for individual farmers (mostly commercial farmers with boreholes) or communities it can be an important source of water. There are no figures on actual groundwater use, but the Inkomati CMA (ICMA) is planning a groundwater use assessment starting in 2009 (ICMA-1, 2008[*]). Similarly, information on water quality (surface- as well as groundwater) is hard to come by. Water quality has not been an issue until now, but with the expansion of cities and townships it is likely to become a bigger issue in the future.

[*] Refers to personal communication. See 'Stakeholder Interview Matrix' on page 31.

1.3.2.3 Soil Type

Soils in the Lower Komati range from fertile soils with high clay content, to marginal, sandy soils (see figures 1.5 and 1.6). During Apartheid commercial farmers had the advantage of access to high potential soils, mainly north of the Komati and Lomati Rivers. Over the years, and with the start of the NIEP, smallholder projects were established on the less fertile soils south of these rivers.

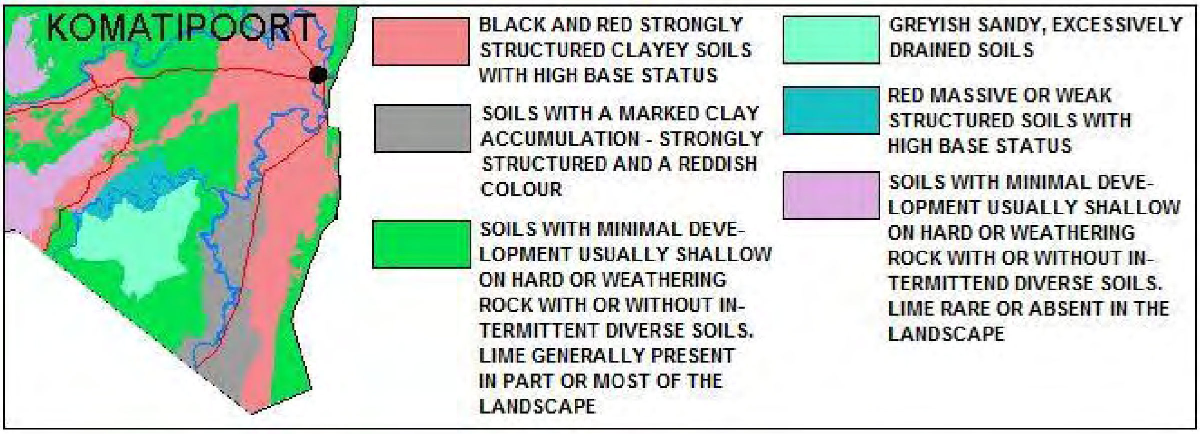


Figure 1.5: Description of soils in the Lower Komati (Department of Environment and Tourism, 2008).

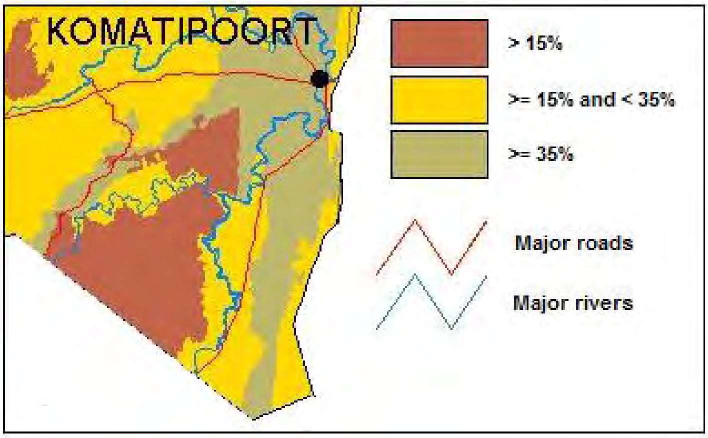


Figure 1.6: Clay classes of the top soil (Department of Environment and Tourism, 2008).

1.3.2.4 Demography

The population of the Lower Komati is estimated to be around 277,600 (DWAF, 2000). Of the total population 98% are (black) African. Due to the homeland history, there is a high population density living in semi-rural areas in large townships. There are no real cities in the area. The area has an estimated population growth rate of 4.8% p.a. It is believed that there is a significant presence of aliens mostly from Mozambique and that the high population growth rate can be ascribed to some extent to the influx of aliens (Nkomazi Local Municipality, 2007).

The area, especially the underdeveloped Southern section is characterized by a very young population. 54% of the population is under 19 years old. 23% is aged between 20 and 34, 16% between 35 and 65, and 4% are over 65 years of age. The population in the Northern section mainly concentrated in and around the formal towns of Malelane, Komatipoort, Marloth Park and Hectorspruit, has a different age break-down. In these areas 36% is under 19 years old. 58% are aged between 20 and 64, and 6% is 65 or older (Nkomazi Local Municipality, 2007).

Unemployment numbers are very high. Over 50% of the people are unemployed, and 48% of the households have no certain annual income. The dependency ration is 6.8, meaning that 6.8 people are depending on the income of one working person. The male absenteeism rate is 30.7, meaning that 30.7% of all employed people work outside the area. 35% of the labour force in the Lower Komati has had no education, 24% attended primary school, 31% attended secondary school, and 5% obtained a diploma at a tertiary institution. Only 0.06% of the population has a university degree. An estimated 24% of the economically active population is illiterate (Nkomazi Local Municipality, 2007).

There are an estimated 71,774 households in the area. Approximately 59% of the households live in brick dwellings. The average household size is 4.7 persons. The people in the townships live in informal housing on state owned land and under tribal authority. The Majority of the households (88% in the Southern part and 73% in the Northern part) earn less than ZAR1000 per month (Nkomazi Local Municipality, 2007). About 2/3 of the people in South Africa are believed to live under the 'bread line' or ZAR10/day. In the Lower Komati, DALA estimated the amount of people with a zero income to be 242,942 in 2001 (DALA, 2005). Only 5% of the population earns more than ZAR3500 per month.

The primary sector, and specifically agriculture, dominates the economy of the Lower Komati, with the highest contribution to the GDP and the highest employment figures. This is true for both the wealthier Northern and the poorer Southern areas (Nkomazi Local Municipality, 2007).

1.3.2.5 Irrigated Agriculture

Agriculture is the main land and water user in the Lower Komati. It falls apart in irrigated agriculture, dry land cultivation and livestock and game keeping. Sugarcane is the main irrigated crop in the area, and the Lower Komati is the only region in South Africa where sugarcane is under intensive irrigation (SASA, 2008a). NIEP has increased the irrigated sugarcane area in the Lower Komati by establishing around 9,800ha of smallholder irrigation plots (23 projects along the Komati River, 9 along the Lomati River, and 2 along the Mzinti River). Large sugarcane farms (totaling around 30,600ha) are mainly found along the Komati River. For agricultural purposes the area relies heavily on surface runoff generated upstream in the Komati and Lomati Rivers to irrigate some 40,000ha of sugarcane (TSB, 2007). Small-scale irrigators of the NIEP only grow sugarcane, while most commercial farmers grow a variety of crops. Vegetables, bananas and citrus are common cash crops for commercial farmers.

Sugarcane

South Africa is the twelfth highest producing country of sugarcane, producing 21,725,100Mton in 2005, compared to 420,121,000Mton for Brazil, the number one country producing sugarcane (FAO Statistics Divisions, FAOSTAT, 2008). The average sugar yield for South Africa was 48ton/ha in 2006, which is rather low compared to other Southern/Middle African countries such as Zimbabwe (83ton/ha), Swaziland (95ton/ha), Zambia (112ton/ha) and Malawi (109ton/ha) (ProdSTAT, 2008). Average sugar yields are 98ton/ha for the commercial farmers and 63ton/ha for the emerging farmers (TSB, 2007). The percentage of ERC (Estimated Recoverable Crystal) is about 12%. This figure is high for South Africa (SASA, 2008a) and emphasizes the good agricultural potential in the Lower Komati.

In the Lower Komati sugarcane has a growing season of 12 months. The sugar harvest takes 38 weeks, starting in April and finishing before Christmas. Farmers' cane delivery agreements (CDAs) mention a weekly delivery of 1/38 of the total harvest. Since this can be costly and difficult to organize, farmers unite in cutter groups. The group delivers to the mill each day of the year, and it allows farmers to cut bigger patches in shorter periods. For small scale farmers this is very important because of their small plot sizes, and they are normally organized within the farmers association. Each individual emerging farmer harvests once a year and thus gets an income from sugar only once a year. Commercial farmers usually spread their harvest to receive an income from cane each month (TSB-5, 2008*).

Farmers get paid based on the amount of sugar and the recoverable value (RV). The introduction of RV% cane is based on sucrose content, non-sucrose content, and fiber content, and takes into account losses in molasses and bagasse. It is based on the income that will be derived from the total industry sales of the sugar and molasses produced in that season. It thus depends on the relative tonnages and prices achieved, and the RV% cane is an estimate that is proportional to the income that will be derived from cane with a particular composition. To allow for changes in composition (and sucrose content) through the weeks of a season, so that the cane price is relatively constant and so that compensation will be fair, an adjustment to RV% cane is made, knows as Relative RV% Cane (SASRI, 2008b).

1.4 INSTITUTIONAL FRAMEWORK

The main stakeholders relevant for this research are the South African Sugar Association (SASA), including the South African Sugar Research Institute (SASRI) and the South African Canegrowers' Association (CANEGROWERS), TSB Sugar, the Department of Agriculture (DoA) including its Department of Agriculture and Land Affairs (DALA), the Department of Water Affairs and Forestry (DWAF), the Inkomati Catchment Management Agency (ICMA) the Komati Basin Water Authority (KOBWA), the Irrigation Boards (IBs), the commercial farmers, and the NIEP emerging farmers.

1.4.1 The South African Sugar Association

The South African sugar industry is regulated by the Sugar Act (1978), which grants statutory powers of self-government to this sector of the agricultural economy. The affairs of the sugar industry are controlled by SASA, who administers the production and supply of sugarcane to the millers and also the production, marketing and distribution of sugar (Kirsten & Sartorius, 2002). SASA administers the partnership on behalf of the CANEGROWERS and the South African Sugar Miller's Association (SASMA) (SASA, 2008b).

SASRI is an agricultural research institute within SASA known for its research into the development of new sugarcane varieties and improved crop management and farming systems. SASRI offers an extension service which provides the link between research and sugarcane farmers. Its primary function is to facilitate the adoption of technology and best management practices for sustainable land use while delivering optimal productivity and profitability (SASRI, 2008c).

CANEGROWERS is a "non-racial", apolitical national organisation within SASA representing South Africa's sugarcane growers. The organisation tries to look after the interests, and create unity among the 50,000 sugarcane growers in South Africa, the majority of whom are small, medium, and micro enterprises, and who, collectively, farm 423,543 ha of sugarcane. CANEGROWERS provides a wide range of services, information and advice with a focus on agricultural economics. In addition, it develops and empowers cane growing communities through the promotion of cane development involving training and information support (CANEGROWERS, 2008).

1.4.2 TSB Sugar

Transvaal Sugar Limited (TSB) is one of five milling companies in South Africa. TSB was founded in 1965 and operates in the province of Mpumalanga with offices in Johannesburg and Durban. In 2004 TSB purchased Booker Tate, a UK based company whose main activity is the management of sugar producing companies around the world. TSB's main activity is the production of sugar, but it is also involved in the production of animal feed (from molasses and sugarcane core), and the cultivation of citrus, subtropical fruit, and tea. TSB employs around 4000 people and contributes substantially to the economy of Mpumalanga. Sugar production increased from 109,500ton in 1975/1976 to approximately 300,000ton in 2000/2001 (Sartorius, 2003). With a current capacity to produce 400,000ton of sugar per year (TSB, 2007), it is responsible for about 20% of South Africa's sugar production (SASA, 2008a). Being the sole purchaser of sugarcane in the Nkomazi area, TSB is an important stakeholder.

The TSB growers include the company estates, and a range of contracted large-medium (commercial) and small-scale (emerging) suppliers/growers. The types of growers differ mainly in the differential farm size and the level of capital investment. In the case of the company estates, the milling company farms large tracts of land. This operation is categorised by a modern capital-intensive mono-cropped sugarcane production system with high levels of management input and control. The electricity generated in the sugar mills is being used on these estates, and they supply around 18% of the sugarcane to the two mills. The second category of grower, the commercial farmer, is also characterised by a modern capital-intensive sugarcane production system with high levels of management inputs (Kirsten & Sartorius, 2002). These farmers are contracted to TSB by way of a long-term specification contract and supply around 60% of the total volume of sugarcane delivered to the two mills (TSB, 2007). Most of these farmers operate farms that are in excess of 100ha and in many cases sugarcane is one of the farm enterprises together with sub-tropical fruit and vegetables. The third category of grower, the emerging farmer, includes more than 1000 small-scale farmers. They supply the final 22% of total sugarcane to the mills. The average farm size of these growers is 6.8 ha with the smallest farm recorded as around 1.5 ha and the largest as 30 ha (TSB, 2007). TSB provides technical support to emerging sugarcane growers in the form of extension work.

The contract, or CDA, signed between the individual growers and TSB extended over a period of 10 years from April 1, 1998. This agreement terminated on March 21, 2008. Because of uncertainty with regard to the Review of the Sugar Act (2002) it has been decided to extend the current CDA for a further period of 12 months until March 31, 2009 (CG-2, 2008*).

In 2005 TSB started its own bank, Akwandze, with the objective to finance emerging farmers. TSB owns 50% of Akwandze while the emerging farmers own the other 50% in the form of shares which they purchased for ZAR1000/ha. With Akwandze, TSB aims to provide access to loans to all emerging farmers. The emerging farmers all have a retention fund which is managed by Akwandze and controlled by SASA. Retention money (ZAR60 per ton/ha) is taken from the farmers' income after harvest. During the following season the farmers receive a monthly pay-out from this retention fund to use for farming inputs such as fertilizers and labour costs (AKW, 2008*).

1.4.3 The Department of Agriculture

The Mpumalanga DoA is responsible for providing support to all farmers in the province. It was formed largely from agricultural departments of the former homeland administrations following the end of Apartheid, and focuses most of its attention on black farmers in the former homelands. DoA's two main roles are, firstly, to provide technical extension to black farmers 'emerging' as commercial producers and supporting investment, operation and maintenance in irrigation schemes, and, secondly, to support applications for water licences to those farmers and allocating water to them (Woodhouse & Hassan, 1999).

DALA is a subdivision of DoA. Just like SASRI and TSB, DALA employs extension workers to assist the emerging sugarcane farmers. The extension workers of the three different organizations come together in the Mpumalanga Extension Forum to ensure that they all convey the same message to the farmers. Unfortunately, DALA is plagued by rapid staff changes which affect the knowledge of the new personnel. As they do not know much about the history of the area it affects their negotiations with DoA and DWAF (DoA-1, 2008*).

1.4.4 The Department of Water Affairs and Forestry

DWAF is responsible for implementing the NWA. The Mpumalanga DWAF regional office in Nelspruit is charged with managing water resources in the Inkomati WMA and the adjacent Olifants WMA. It is responsible for reviewing all water licence applications, registration of licences, verification of registered water use, maintenance of dams and other infrastructure, and compliance with international obligations (Brown & Woodhouse, 2004). DWAF is also responsible for reviewing water allocation demands. It currently refuses to grant any more water licenses. Reasons for this are the perceived general lack of water in the basin, and the need to protect against risk. Moreover, DWAF wants to wait for a complete picture of the needs to assess the amount of water still available, and hence the amount of water that could be reallocated. This global assessment will be achieved through a Compulsory Licensing Process (CLP). The assessment of the current need for water is disputed by the Mpumalanga DoA. According to an initial agreement between the Republic of South Africa (RSA) and Ka Ngwane, there are still 30 MCM of water available. However, the legal value of this past agreement is unclear under the new dispensation, and DWAF argues that there is just no more water available (Faysse & Gumbo, 2004). Thus, despite requests from black communities for further irrigation, no further allocations of water have been made for at least seven years as local offices of DWAF and DoA engage in arguments whether sufficient water is available to supply new agricultural projects (Woodhouse, 2008). At the time of this research (late 2008) the DWAF office in Nelspruit only existed on paper due to several rapid staff changes. The few remaining staff had been transferred to the ICMA.

1.4.5 The Inkomati Catchment Management Agency

The ICMA represents the interests of different water uses at catchment level, following the NWA principle of decentralization of water management in the WMA. The NWA provides that DWAF may delegate far-reaching powers to the ICMA, phased out over time, and that the ICMA will effectively take over many of the operational functions from the DWAF regional office in Nelspruit (Woodhouse, 2008). The ICMA was officially launched on March 30, 2004, but the implementation has been characterized by struggles between the main local water users (mainly the white commercial farmers) and the officials of the DWAF National headquarters in Pretoria. Transfer of technical (water resources management) staff from the DWAF regional office happened in 2007, but due to conflicts between the new ICMA staff and the DWAF national office, powers have still not been delegated down (November 2008). As there is no effective regional DWAF office, the ICMA is approached by local organizations such as the IBs to help with water management. However, as DWAF still doesn't deem the ICMA a responsible authority, this leaves the ICMA staff with not much to do (LIB-1, 2008*; ICMA-1, 2008*). This frustrates the ICMA, who accuses the DWAF head office in Pretoria of not communicating, and of taking decisions over their heads. It also frustrates the IBs who refuse to share data of individual water use of the farmers with the ICMA. They do not want this information to end up at the DWAF office in Pretoria, who they believe to be incompetent, knowing nothing about the local situation in the Lower Komati (LIB-1, 2008*; WW, 2008*).

1.4.6 The Komati Basin Water Authority

The Komati Basin Water Authority (KOBWA) was established in 1993 under the terms of the international treaty on the 'Development and Utilization of the Water Resources of the Komati River Basin' between South Africa and Swaziland. KOBWA was charged with the design, building and management of Driekoppies dam in South Africa, and Maguga dam in Swaziland. Its role is to manage the dams to satisfy the needs of the farmers whilst meeting international legal requirements (KOBWA, 2008). KOBWA is charged with the daily management of major water infrastructure and all management decisions must be in accordance to the treaty of which KOBWA is the custodian. In times of drought, KOBWA decides the water restrictions of the farmers using decision support tools. KOBWA also manages the RAP (Relocation and Planning) area of Schoemansdal and Middelplaas, as these farmers were forced to move when the dam was built (KOBWA-1, 2008*).

1.4.7 Irrigation Boards

The Lower Komati is part of a Government Water Control Area (GWCA) which means that it is mandatory for irrigators to be members of an IB. The two IBs in charge of managing water in the Lower Komati are the Lomati IB (LIB) and the Komati River IB (KRIB). These were created to control the amount of water pumped by commercial farmers during periods of drought. In 1995-1996 both IBs' areas of jurisdiction were broadened to encompass the small-scale growers (Faysse & Gumbo, 2004). IBs are the effective day-to-day managers of the resource at local level and are responsible for water distribution among many stretches of the rivers. Allocation of water to agriculture is based on a quota system set by IBs. The maximum quota is set at 9,950m^3/ha/annum for the Komati River, and 8,500m^3/ha/annum for the Lomati River (KRIB-2, 2008*; LIB-1, 2008*). The IBs receive water allocations and restrictions from KOBWA, and allocate this to the farmers according to the seasons. This is done in the form of weekly irrigation hours that are usually sent to the farmers by text-message.

The 1998 NWA launched an in-depth reform of water resource management. At the local level, all IBs were to be transformed into WUAs. These WUAs are expected to incorporate all users in the defined area of jurisdiction, whether they have a formal water entitlement or not. It is believed that this transformation will enable better participation of historically disadvantaged individuals (HDIs) in the management of water resources. It will also provide a basis for improving local integrated management of water resources (Faysse & Gumbo, 2004). The two IBs in the Lower Komati had not been transformed into WUAs by November 2008. The IBs are willing to transform, but feel they are being held back by DWAF who they believe to be reluctant to give away powers (LIB-1, 2008*).

Overall, commercial farmers are in a potentially strong negotiating position within the IB as they possess the most detailed local knowledge of water use by agriculture. Also, as the largest water users, they will contribute the largest proportion of the Water Resource Management Charge, and therefore IBs will be largely financially dependent on this sector. TSB also wields considerable power over its growers and the IBs as its managers simultaneously hold positions of responsibility in the local IBs. Farmers have a vested interest in the IBs, as they work on a lower level, where it matters. They believe in the skills of the IB staff, and want to be represented on the IBs. They do not generally care about the DWAF or ICMA who they believe to have no capacity for water management (CF, 2008♦). In theory, the IBs are supposed to take instructions from the ICMA, but this is exactly where the breakdown is, as the ICMA claims to have no executive powers.

1.4.8 Commercial[1] Farmers

Large scale commercial farmers live and farm in the former 'white' part of the Nkomazi/Onderberg area. In the Lower Komati Basin there are around 120 farmers (80 in the Komati, and 40 in the Lomati) cultivating an area of 30,600 ha (TSB, 2007). Some of these large scale farmers are second or third generation farmers, but many of them bought farms here and come from other regions. They are on average highly educated, and have capital intensive farms with a variety of crops. Their land often comprises several hundreds of hectares. They employ many people, grow a variety of crops, export the crops or sell them to the local market.

The commercial farmers have a strong community and have always been active in collective action like building weirs and forming pressure groups to influence the government. As irrigated agriculture in the Inkomati has historically been the preserve of white commercial farmers, who, through membership of IBs, have a long tradition of organization to secure access to water, most of the government's investment in storage dams in the Inkomati WMA has been designed to serve their needs (Waalewijn, 2002).

When it comes to water management, commercial farms are managed independently at field level. River water is stored behind a weir, owned by the IB. Many farmers have reservoirs, and irrigation water is pumped from the river into the reservoir on the farm. The reservoirs are used for flexibility in operation of the pumps, and to profit from cheap power during the

[1] The term 'commercial' can sometimes be confusing. Commercial farming traditionally referred to white farmers cultivating large tracts of land. However, with Land Reform, some commercial land has been transferred to black communities, and is now managed by black farmers. In this report 'commercial farming' will refer to the large scale white farmers. Former commercial land that is now owned by black communities will be referred to as 'Community Land'.

night. An important function of the reservoir is to increase the water security. Commercial farmers use a broad range of irrigation equipment for their variety of crops. There is a tendency towards drip irrigation, and drag hose irrigation has become increasingly unpopular due to the labour intensity. However, there is much over-irrigation due to improper scheduling and operation (TSB-4, 2008*). Commercial farms are located one after the other on both sides of the Komati River, and north of the Lomati River (figure 1.7).

1.4.9 NIEP Emerging[2] Farmers

Emerging farmers are black farmers moving from subsistence to commercial farming. There are around 1500 emerging farmers in the Lower Komati spread over 34 projects. Together they cultivate a total area of 9,800 ha (TSB, 2007) (figure 1.7). There are 23 projects along the Komati River ('The Komati Projects'), 9 projects along the Lomati River, and 2 projects along the Mzinti River (known together as 'The Malelane Projects'). For a more detailed view of the projects see Annex I.

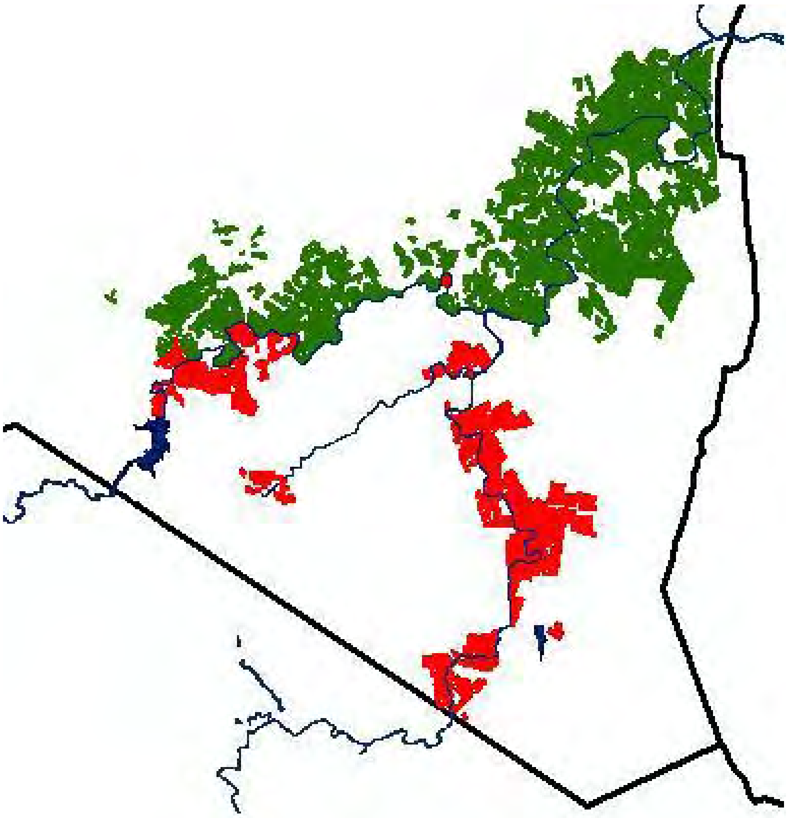


Figure 1.7: The locations of commercial farmers (green) and emerging farmers (red) in the Lower Komati (TSB, 2007).

As a consequence of the labour and land policies under Apartheid, black farmers do not have a long history of irrigated farming in the Inkomati WMA. As the NIEP schemes are relatively young, emerging black farmers are still relatively inexperienced in the day to day operations of high input farming. They have yet to develop strong social networks (Brown & Woodhouse, 2004). The emerging farmers in the Lower Komati, who have been targeted for development assistance, are all members of IBs. When it comes to water management, the

[2] The term 'emerging' refers to black smallholder farmers moving from subsistence to commercial farming. However, not all black farmers are truly emerging. Some successful emerging farmers are competing on the same level with commercial farmers when it comes to yield (ton/ha). Others have expanded their land and can now be regarded as middle-scale farmers.

biggest difference with commercial farmers is that commercial farms are managed independently at field level. The emerging farmers are part of an irrigation scheme, which limits the choices at field level and requires forms of organization. Most NIEP schemes have dragline sprinklers. The water is pumped from the river using a communal pump. Sometimes the water is stored behind a weir, but many weirs have not been rebuilt after being destroyed by floods. The pump lifts the water to a stilling basin with a storage capacity of one day irrigation from which the water is pumped to field outlets in different blocks. There the system is connected to sprinkler systems that farmers rotate on their plots. In all the irrigation schemes, farmers are organized into a farmers' association, charged with all farming-related aspects of the scheme.

Just as the commercial farmers, the emerging farmers must sign a 10-year contract with TSB. This CDA prohibits them from converting their land to other crops. There are undoubtedly advantages to the contract with TSB as it is claimed to be an appropriate length of time for people who know nothing of farming; and it provides technical support, security and access to loans (Brown & Woodhouse, 2004). On the negative side it hands a lot of power to TSB that may ultimately stifle diversification. TSB has a strong interest in seeing that emerging farmers make a success of the NIEP, thereby ensuring a reliable supply of cane for its expanded processing capacity at Komatipoort. Unsurprisingly, the perception of sugar as an inherently inefficient crop which uses too much water in a water-stressed region is challenged by TSB (Brown, 2008).

1.5 PROBLEM DEFINITION

NIEP started a challenge of black empowerment, with the objective to promote the economic development of the Nkomazi region. Its aim was to provide funding, support and resources for 960 black farmers spread over an initial 7,200ha (over the years this number increased to 9,800ha). Sugarcane was chosen as a stepping stone out of poverty and as a livelihood strategy for black farmers. It was assumed that sugar would help them emerge as commercial producers, transforming their farming systems to those associated with commercial production. In order to start this agricultural transformation of poor smallholder farmers to commercial farmers, NIEP provided the smallholders with a technological package, including land and water access, technical support and managerial advice. TSB was, and still is, part of the technological package offered by NIEP, as it provides the farmers with many services such as extension, loans, irrigation, transport, logistics and a guaranteed market. It also takes charge of pump maintenance. However, it is unknown to what extent the agricultural transformation process as intended by NIEP has been completed in the Lower Komati, and how this has affected the farming system of the emerging farmers. This research will therefore explore the different farming systems in the Lower Komati, as well as the way these have been affected since the start of NIEP.

Additionally, a study done by remote sensing company WaterWatch (Soppe *et al.*, 2006) showed that there is a great variety in the evapotranspirative consumption of water and the associated biomass formation among the farmers in the Lower Komati. This is true for the commercial farmers as well as the emerging farmers. Moreover, this research showed that the spread of biophysical crop water productivity for emerging farmers appeared smaller than the spread of this value for commercial farmers. WaterWatch's SEBAL (Surface Energy Balance Algorithm for Land) analysis also, surprisingly, showed that when it comes to the productivity of emerging farmers in general, they perform very well compared to the commercial farmers. There is no clear understanding of the reasons for the great variety in evapotranspiration and biomass growth among the farmers in the Lower Komati. Similarly, it is unclear why the emerging farmers seem to do very well when it comes to biophysical crop water productivity. This research will elaborate on the study done by WaterWatch and explore the diversity of *actual evapotranspiration (ET_a)*, *biomass*, *yield*, and *crop water productivity (CWP)* of all farmers in the Lower Komati on a field-by-field basis. Furthermore, these four parameters will be used as indicators for the socio-economic development objectives of the NIEP, assuming that fields with high ET_a, high biomass, high yield production and/or high CWP belong to farmers with a more commercialized ('socio-economic developed') farming system. This also assumes that the NIEP, by helping the smallholders produce sugarcane, aimed to lift their levels of ET_a, biomass, yield production and CWP to levels associated with the sugarcane production of commercial producers.

1.6 OBJECTIVES

Following the problem description, the objectives of this research are:

- To analyze the evapotranspirative water consumption, biomass formation, yield production, and crop water productivity of sugarcane in the Lower Komati;
- To explore the diversity in actual evapotranspiration, biomass, yield production, and crop water productivity among the commercial and emerging farmers in the Lower Komati on a field-by-field basis;
- To investigate the farming systems of the commercial and emerging farmers in the Lower Komati;
- To investigate the nature of the technological package as part of the farming systems in the Lower Komati;
- To investigate whether and how the NIEP has contributed to rural transformation i.e. a change in farming system from 'emerging' to 'commercial';
- To relate the diversity in actual evapotranspiration, biomass, yield production and crop water productivity of the farmers in the Lower Komati to their farming systems and socio-economic development.

This chapter presented the necessary background information on the research area, and introduced the stakeholders involved. The problem definition and objectives set the base for the conceptual framework that will be discussed in the next chapter.

CHAPTER 2: CONCEPTUAL FRAMEWORK AND METHODOLOGY

The previous chapter presented the necessary background information on the research area and introduced the stakeholders involved. The problem definition and objectives defined in chapter 1 will set the base for the conceptual framework that will be discussed in this chapter. This conceptual framework will set out the structure of this report, and together with the problem definition it will lead to a formulation of the research questions and methodology.

2.1 CONCEPTUAL FRAMEWORK

2.1.1 Evapotranspiration and Biomass

Evapotranspiration (ET) is the combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration. Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the topsoil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process (FAO, 1998).

When calculating the ET values of fields for longer periods, these can be used to monitor the total volume of water consumed from a water district for a month, season or year. These values can be used by water managers to evaluate their irrigation scheduling performance (Soppe *et al*., 2006). The distribution of ET, or consumed water, within a water district also gives information about the water users. Some farms will use more water than other farms. This information can be then combined with the measurements of yield production.

Biomass production is based on solar radiation absorption by chlorophyll and the conversion of this energy into a dry matter production and is directly related to yield (Bastiaanssen & Ali, 2003). A good understanding of water consumption and yield response of crops growing under variable environmental conditions is essential for efficient and sustainable agricultural and environmental management. These crop water relationships are often described using two main observations. Firstly, biomass is linearly related to transpiration throughout the life span of crops under varied natural conditions and levels of environmental stress (Ben-Gal *et al*., 2003; De Wit, 1958; Hanks, 1974). This relationship is described in relative terms by Hanks (1974):

$$\frac{B_a}{B_p} = \frac{T_a}{T_p} \qquad (2.1)$$

where B and T are biomass and transpiration respectively and the subscripts *a* and *p* represent actual and potential. The general assumption is that this relationship also holds true for biomass and ET, as during full crop cover over 90% of ET comes from transpiration (FAO, 1998). Secondly, conditions of limiting water and low fertility e.g. high salinity or a toxic substance, decrease yield (Ben-Gal *et al*., 2003; De Wit, 1958; Shani and Hanks, 1993).

Crop-physiological factors such as *water quantity* and *soil fertility* thus influence ET and biomass, and may help explain the diversity in ET and biomass within an area. However, water and fertility are complex issues, as they are not merely crop-physiological in nature. Water quantity, for example, is not only depending on the crop-physiological factor of climate (which is affected by e.g. rainfall, temperature and humidity) but also on the socio-economic factor of irrigation which includes timing, precision and control of water. In the same way, soil fertility does not only depend on the clay content of the soil (an indicator for fertility), but is also related to water quantity in a crop-physiological way (climate) and in a socio-economic way (irrigation). Moreover, soil fertility depends on inputs such as fertilizers, which are related to farming systems.

2.1.2 Yield and Crop Water Productivity

The conversion of total above ground biomass development B_{act}^{tot} into crop yield Y_{act} depends on the crop parameters h_{ind}, the harvest index of sugarcane, and m_{oi}, the water content of sugarcane during harvest (Bastiaanssen & Ali, 2003):

$$Y_{act} = \frac{h_{ind} B_{act}^{tot}}{1 - m_{oi}} \text{ (kg/m}^2\text{)} \tag{2.2}$$

Yield is defined as the quantity of sugarcane produce (e.g. in kg/m^2) and is directly related to biomass. However, yield production of sugarcane is not as straightforward as it might appear. Two aspects of sugarcane yield are important to the farmers as they are used for payment purposes in South Africa: the harvested cane in tons/ha and the RV% (percentage of recoverable value) (SASRI, 2008b). Multiplying the tons/ha with the RV% and the sugar price gives a good indication of the farmers' income.

The composition of sugarcane is shown in figure 2.1 with some typical percentages. Sucrose is the valuable component of cane, with sugar being almost pure sucrose. Excessive fibre content is a disadvantage as it uses up milling capacity and reduces the amount of sucrose that can be extracted. A low purity, which is generally the same thing as a high non-sucrose content, is wasteful because either the cane is not properly ripe, or it has been allowed to deteriorate. In addition, less of the sucrose can be recovered at the mill, reducing the amount of sugar that can be made (SASRI, 2008b).

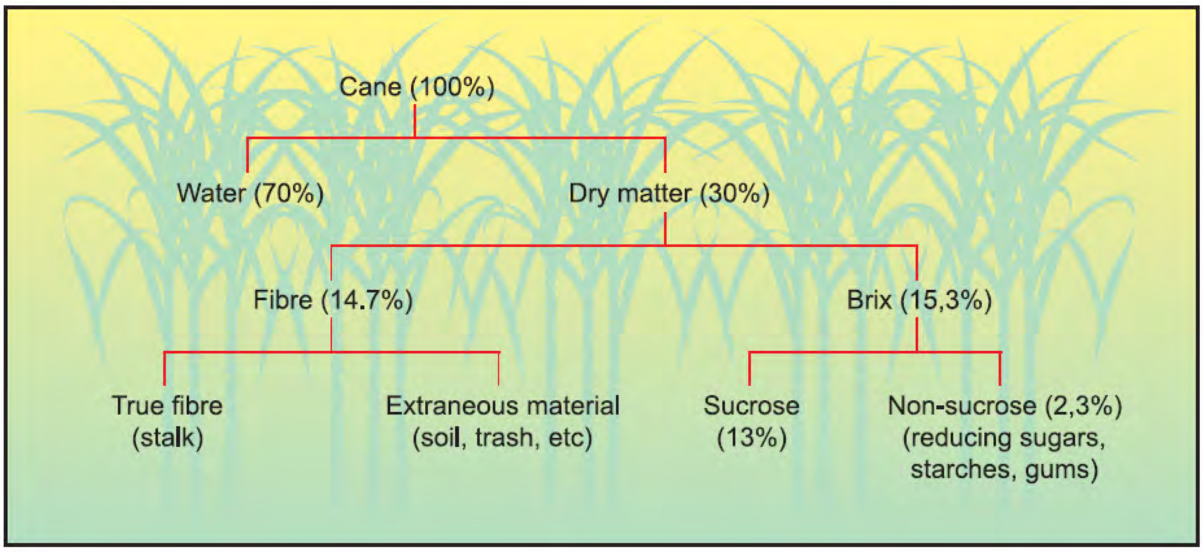


Figure 2.1: Composition of Sugarcane (SASRI, 2008b).

The RV cane payment formula penalises growers for the amount of non-sucrose and fibre delivered in cane. However, more than 90% of RV still consists of sucrose. Therefore, growers need to apply every measure possible to maximise sucrose production per hectare. This can be done by adopting three basic principles. Firstly, cane needs to be well grown and mature when harvested, having the maximum possible sucrose yield per hectare. Cane needs to be harvested at the appropriate age and the appropriate time of year for the variety concerned. Secondly, at harvest growers should ensure that the cane is as clean as possible. There should be a minimum of extraneous manner such as roots, leaf material and soil with the cane. Thirdly, cane needs to be fresh when it reaches the mill. Cane should be delivered and crushed within 48 hours of harvest (SASRI, 2008b).

As can be seen in figure 2.1, a higher water content in sugarcane affects the tons/ha positively, but the sucrose content negatively. On the other hand, water stress in sugarcane affects the sucrose content positively while the tons/ha go down. Within the irrigation scheduling of sugarcane, the practice of drying off the cane 4-6 weeks before harvest is used to increase moisture loss, and thus increase the sucrose content (and the RV%) of the cane to boost the profits. It must be noted, however, that cane can not be left lying in the field more than 48 hours after harvest. This will increase the sucrose content, but in addition to moisture loss, it will also cause physical loss of cane (TSB-2, 2008[*]). It will thus result in a loss of income for the farmer. The yield expressed in RV% concerns the socio-economic aspect of income and is related to the farming system.

Crop water productivity (CWP) is defined as the productivity of water related to the yield derived from the use of water i.e. the yield per unit of consumed water (kg/m^3) (Bos, Burton & Molden, 2005). In order to be able to calculate the CWP using remote sensing, it is expressed in ET (Y_{act} per unit of ET). CWP is thus estimated using the physical yield in tons/ha of cane:

$$CWP = \frac{Y_{act}}{ET} \text{ (kg/m}^3\text{)} \tag{2.3}$$

High productivity is generally achieved when high yield uses little water. This depends on the type of crop (although this thesis will focus on a single crop only: sugarcane) and the socio-economic aspects of farming. CWP is linked to management and can indicate areas of high management and areas of low management. Linking ET and crop yield to CWP can be relevant for commodity groups such as TSB Sugar to optimize water use and increase crop yields, thus increasing the sugar production.

2.1.3 Farming Systems

In the Lower Komati sub-catchment, 120 commercial farmers and over 1500 emerging farmers are all involved in sugarcane farming. The farming systems of these farmers will be explored in this research. A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate (Dixon *et al*., 2001). There are no general agreements as to the boundaries of a farming system, or to its determinants. Norman's (1980) concept however, has found considerable acceptance (see figure 2.2). Norman recognizes human and technical elements;

[*] Refers to personal communication. See 'Stakeholder Interview Matrix' on page 31.

exogenous and endogenous factors and the usual inputs used in economics: land, capital, labour and management (Norman, 1980 and cited in Beets, 1990). Beets (1990) developed a model of common determinants and interactions in a tropical farming system as can be seen in figure 2.3. He takes three groups of factors: physical, socio-cultural, and political and institutional. Physical factors can be divided into those that can be controlled by the farmer, e.g. erosion and flooding, and those beyond his control, e.g. climate. The political and institutional factors can be divided into those that have direct effects, e.g. credit, input subsidies, and those that have indirect effects, e.g. import and export policies. The socio-economic factor of soil fertility, which depends on fertilizers (inputs) and affects the ET and biomass, will be further explored within this farming system framework.

Each farming system can be classified into a category based on criteria such as the available natural resource base, the dominant pattern of farm activities, and household livelihoods. The commercial farmers in the Lower Komati can be classified into a *Commercial Farming System.* These farming systems are characterised by a modern capital-intensive sugar cane production system with high levels of management inputs. These (white) farmers are contracted to a private agribusiness company (TSB) by way of a long-term specification contract. Most of these farmers operate farms that are in excess of 100ha and in many cases sugarcane is one of the farm enterprises together with sub-tropical fruit and vegetables. These farmers are on average highly educated. They employ many people, export the crops or sell them on the local market (Kirsten & Sartorius, 2002). These farms are managed independently at field level, and commercial farmers use a broad range of irrigation equipment for their variety of crops.

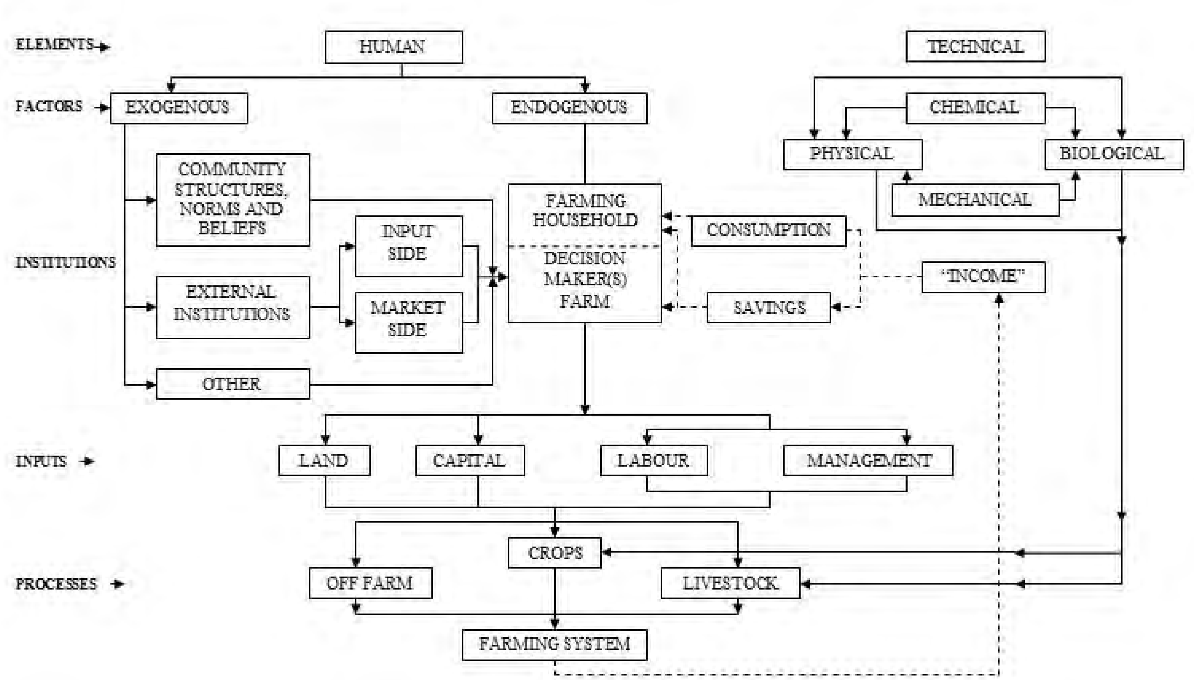


Figure 2.2: Schematic Representation of major determinants of farming systems (Norman, 1980, as cited in Beets, 1990).

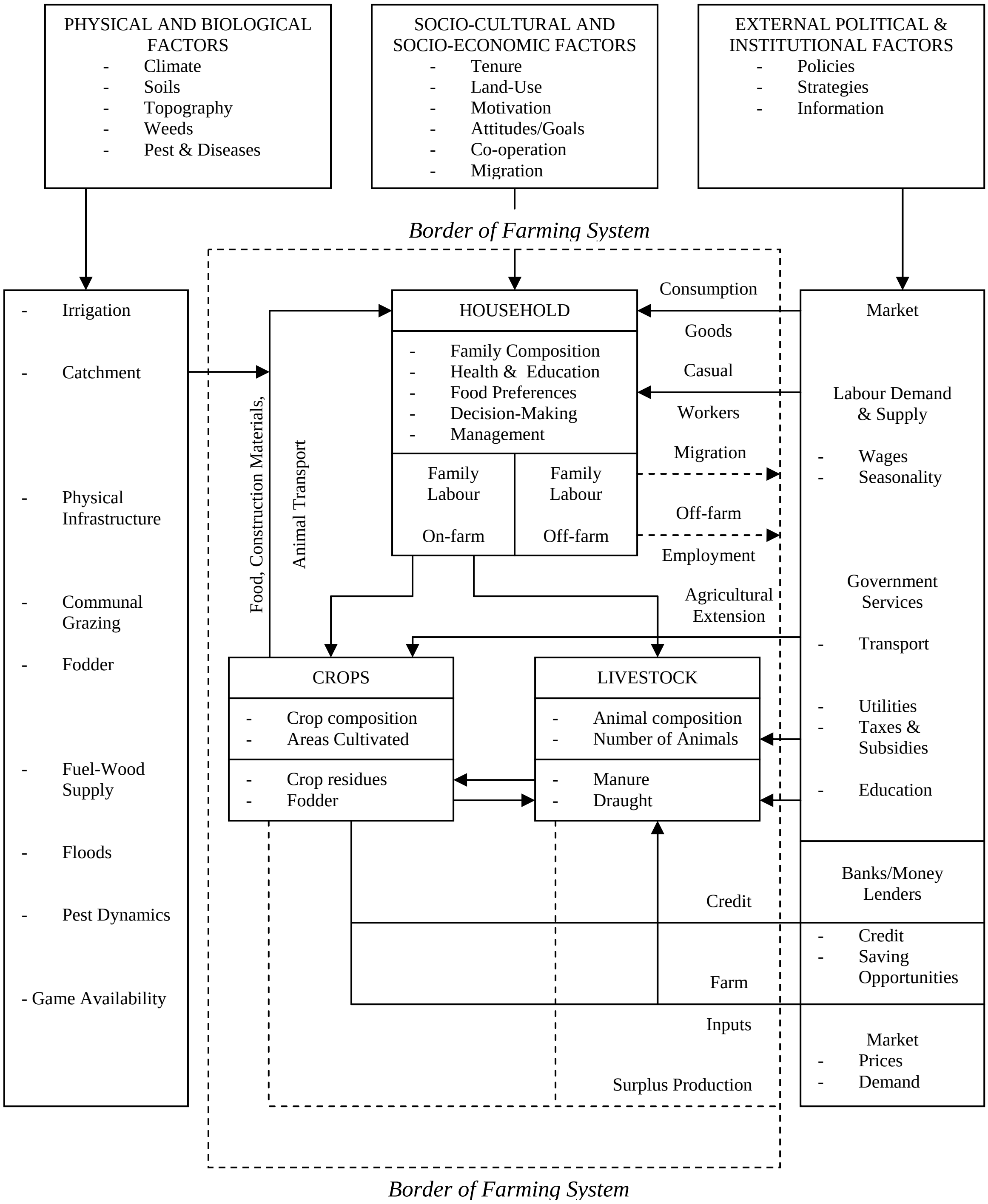


Figure 2.3: Model of common determinants and interactions in a tropical smallholder farming system (Beets, 1990)

The emerging farmers in the Lower Komati can be classified into an *Outgrowers Farming System* or *Contract Farming System*, which also involves an agreement between the black smallholders and a private agribusiness company (TSB). Services offered by the agribusiness include provision of credit inputs, extension advice and transport of produce. The emerging farmers then have the benefit of an assured market, and the opportunity for commercialization.

With effective management, contract farming can be a means to develop markets and to bring about the transfer of technical skills in a way that is profitable for both sponsors and farmers (Eaton & Shepherd, 2001). The emerging farmers are often uneducated, and are relatively new at farming. Many are plagued by poverty. Their farms are part of an irrigation scheme, which limits the choices at field level and requires forms of organization. The emerging farmers farm small plots of land which are entirely for sugarcane production. Many have a little vegetable plot for home consumption.

With actual evapotranspiration (ET_a), biomass, yield production and CWP being indicators for socio-economic development, it is assumed that fields with high ET_a, high biomass, high yield production and high CWP belong to farmers with a more commercialized ('socio-economic developed') farming system. The rural transformation objectives of the Nkomazi Irrigation Expansion Programme (NIEP) are therefore influencing the farming systems of the emerging farmers as NIEP aims to lift their levels of ET_a, biomass, yield production and CWP to levels associated with the sugarcane production of commercial producers. In order to do so, NIEP provides funding, support and resources to the emerging farmers, and provides them with a technological package for rural transformation. TSB is part of the technological package offered by NIEP, as it provides the farmers with many services such as extension, loans, irrigation, transport and logistics. The technological package is thus part of a transition model which plans to change the 'traditional' outgrowers farming system into a commercial farming system. This thesis will assess to what extent the farming systems of the emerging farmers have been transformed into commercial farming systems, and will thus analyze the variety of ET_a, biomass, yield production and CWP among these systems. It will also explore the characteristics of the 'new' emerging farming system that has been formed during this transformation.

In conclusion, the diversity in ET_a, biomass, yield and CWP can be used to explore the diversity in socio-economic development among the farmers in the Lower Komati. These indicators are influenced by the transition model which aims to improve ET_a, biomass, yield, and CWP of farmers as they are in the process of transforming from an emerging farming system to a commercial farming system. This research will therefore attempt to explain the diversity in ET_a, biomass, yield, and CWP by linking it to the different types of farming systems in the area, and their dynamics within the transition model.

2.2 RESEARCH QUESTION

Following the problem definition and the conceptual framework, the research question can be formulated as follows:

"What are reasons for the diversity in ET_a, biomass, yield production and CWP among commercial and emerging farmers in the Lower Komati sub-catchment, South Africa?"

Socio-Economic Development and its Indicators

- What is the distribution of ET_a among sugarcane plots in the Lower Komati?
- What is the distribution of biomass among sugarcane plots in the Lower Komati?
- What is the distribution of yield production among sugarcane plots in the Lower Komati?
- What is the distribution of CWP among sugarcane plots in the Lower Komati?

Exploring the Diversity in Socio-Economic Development i.e. the diversity in ET_a, Biomass, Yield Production and CWP

- What are reasons for the diversity in ET_a, biomass, yield production and CWP among sugarcane farmers in the Lower Komati?
  - What are favourable factors for high ET_a, biomass, yield, and CWP?
  - What are constraints for high ET_a, biomass, yield, and CWP?
  - What are manageable factors influencing ET_a, biomass, yield, and CWP?
  - What are non-manageable factors influencing ET_a, biomass, yield, and CWP?

Farming Systems and their Characteristics

- What are the characteristics of an 'emerging' farming system?
- What are the characteristics of a 'commercial' farming system?
- What are the characteristics of the technological package(s) within these farming systems?
- Has NIEP contributed in a rural transformation from emerging farming systems to commercial farming systems?

Relating Diversity of ET_a, biomass, yield production and CWP to the different Farming Systems

- Do fields with high ET_a, biomass, yield, and CWP relate to farmers with a commercial farming system? Why (not)?
- What is the farmers' dependency on sugarcane?
  - Emerging farmers vs. commercial farmers
- What is being done to overcome the farmers' constraints?
  - Emerging farmers vs. commercial farmers
- Have the socio-economic objectives of NIEP been reached?

2.3 METHODOLOGY

After outlining the structure of this report in the conceptual framework and the research question that followed from the problem definition, this paragraph will concentrate on the methodology used for answering the research question.

This research is divided into two parts. The first part is a technical analysis of remote sensing images, including the ET_a of sugarcane for a one year period (2004/2005), and the resulting hydrological implications of these measurements. The first part of the research quantifies the four indicators used as indicators for socio-economic development: *ET_a, biomass, yield production* and *CWP*. The second part of this research is a secondary analysis and interpretation of the technical data. This secondary analysis includes social and economic indicators, aiming to illuminate the indicators of water use and productivity between commercial and emerging farmers.

2.3.1 Implementation of SEBAL Analyses in Water Management

The technical study used satellite images combined with a surface energy balance model (SEBAL) to calculate ET_a[3] and biomass production for sugarcane areas in the Lower Komati sub-catchment on a pixel by pixel basis, based on the energy balance for each pixel. The energy balance was calculated for each date that the satellite images were taken, and the

[3] Throughout this report the term evapotranspiration will be used interchangeably with the term "consumed water" meaning the water that evaporates from any surface (wet soil, lakes, wet foliage) or transpirates through natural or agricultural plants.

resulting values are therefore variable in space as well as in time. A subset of sugar cane was made based on a land use classification developed by DWAF, GIS data provided by TSB, and my own interpretations from Google Earth. The actual consumed water, ET_a, was calculated based on the energy balance, while the biomass production was calculated based on the NDVI (Normalized Difference Vegetation Index) and the available solar radiation. After calculating the ET_a and biomass production for each pixel, the values of these pixels were averaged over fields to get a single value for ET_a and biomass production respectively per sugarcane field. The values calculated for any single day were then extrapolated for a longer period (one season) based on the known bio-physical behaviour of plants and trees. Subsequently, the ET_a and biomass values were used to calculate the actual yield and CWP for the sugarcane fields in the Lower Komati. A complete overview of these SEBAL calculations can be found in the Technical Annex.

The period of May 2004 to May 2005 was selected for analysis, depending on suitable (and available) satellite imagery. As Landsat images are recorded about once every two weeks, it can be challenging to find good quality images. Between 8 and 24 images per year are usually needed for a complete analysis. The more images used for a specified period, the more precise the analysis will be. In this SEBAL application 9 Landsat images were used spread over the 2004/2005 season. This depended on availability recent images of good quality. Due to high cloud cover during the summer period, the quality of the Landsat was poor for the period between October and February. A cloud mask was applied to these images. An integration of two other images (one before and one after) was used to replace the missing data.

Figure 2.4 shows the Water Management Areas (WMAs) in South Africa, including the Inkomati catchment which was selected as the case study catchment, and the area covered by the Landsat images used for the analysis (path 168 – row 78). Landsat images provide high resolution images for detailed small area analysis. The resolution of the Landsat results is presented as a 28.5m resolution. The high resolution of Landsat makes this satellite highly valuable for agricultural and water resources management. The purpose of using Landsat is to present methods that can be used to compare water productivity between farms (emerging farmers vs. commercial farmers) The Landsat results also provide the input data for the social and economic indicators in the second part of the study.

2.3.2 Secondary Analysis of Technical Data

Following the technical analysis of remote sensing images in order to quantify the ET_a, biomass, yield, and CWP of sugarcane fields in the Lower Komati, the second part of this research focused on interpreting the technical data. The second part of the research was carried out on location in the Lower Komati sub-catchment in South Africa. The secondary analysis reviewed the variation of ET_a, biomass, yield production and CWP between two farming systems in the Lower Komati (commercial vs. emerging). This was done both crop-physiologically and socio-economically. Within the arena of irrigation and irrigation efficiency, the issues in the sub-catchment were regarded as being socio-technical in nature.

This research focused mainly on the perceptions of the different stakeholders in regard to the variation in ET_a, biomass, yield production and CWP. Therefore, the primary data collection process consisted of individual and group interviews with key informants selected from the various stakeholders. Approximately 120 people were directly consulted. Farmers were consulted using a questionnaire focusing on their perceptions of the problems related to the variety in ET_a, biomass, yield production and CWP. They were asked about farm characteristics such as farm size, yield, irrigation type and storage possibilities. They were also asked about general household characteristics such as household size and composition, education, and income in order to get insight into their farming systems.

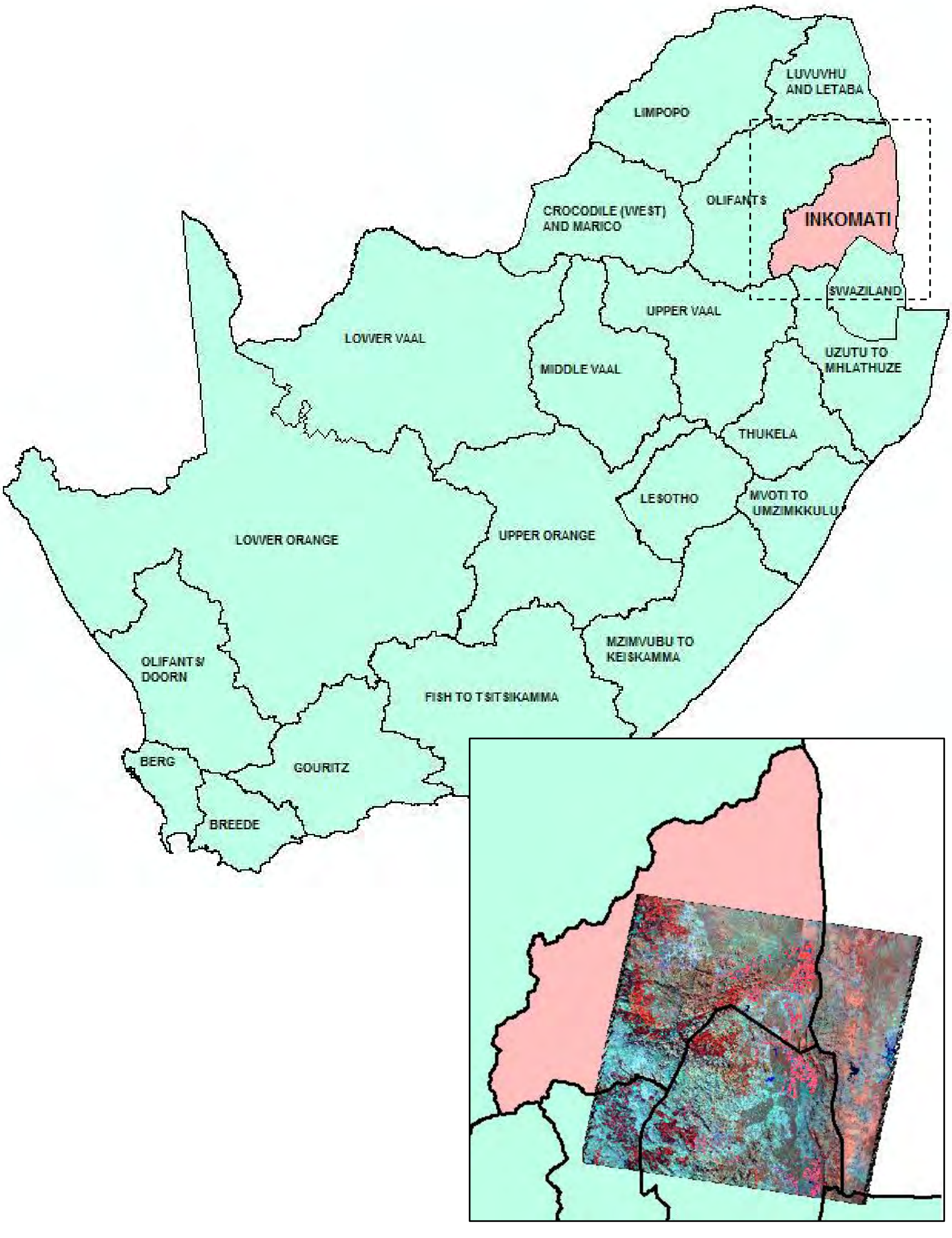


Figure 2.4: Water Management Areas in South Africa. The subset image shows the location of the Landsat images (path 168 – row 78) relative to the Inkomati Catchment.

The aim was to talk to at least 5% of the farmers, and this resulted in interviews with 85 emerging farmers and 11 commercial farmers. Of the 1523 emerging farmers, individual interviews were scheduled with 68 emerging farmers based on a stratified sample. Of each of the 34 projects, one farmer with high ET_a, high biomass, high yield and/or high CWP was randomly selected, as well as one farmer with low ET_a, low biomass, low yield and/or low CWP. The remaining 17 farmers were randomly selected from all projects based on interesting characteristics (e.g. high ET but low yield). Most farmers were interviewed individually.

Approximately 10 farmers were interviewed in a group setting in which the questionnaire was used as a checklist to guide the conversation. Selected farmers who were not interviewed (e.g. because of miscommunication, traffic jams, or other factors) were replaced by farmers in the field who agreed with being interviewed on the spot. This also included data clerks or field technicians. The interviews with the emerging farmers were carried out with the help of an interpreter. Of the approximately 120 commercial farmers, 10 were selected based on the same criteria as the emerging farmers (five along the Komati River and five along the Lomati River). One farmer along the Crocodile River was interviewed for comparison. The interviews with the commercial farmers were carried out in English. Personal communication from these interviews will be cited in this report as being from either CF (commercial farmers) or EF (emerging farmers).

The other stakeholders were consulted using semi-structured interviews. These interviews were done using a checklist to ensure that important issues were discussed. A stakeholder interview matrix can be seen below. The superscripts indicate different positions taken up by the same people. It must be noted that some of these people were farmers themselves (either emerging or commercial).

Besides conducting questionnaires and semi-structured interviews with the appropriate stakeholders, additional data was collected during field visits. Extension workers (TSB, DALA and SASRI) and cane grower officers (TSB) were joined in their visits to the field, during which they were interviewed during short informal talks. Moreover, my own observations during these field visits, as well as my observations during the interviews, were an important source of data. I joined several meetings and trainings of Farmers Associations during my visits to the fields, as well as two Grower Information Days organized by SASRI/TSB, and CANEGROWERS respectively.

During the research period all information that I regarded as useful was written down in a field notebook. This was the notebook I took to the field each day, and which included notes on meetings I attended, as well as my observations. A second notebook was used to write down information that was given to me while conducting the questionnaires and interviews. Each afternoon the interviews were typed out on my laptop. The questionnaires were saved in a standard format. The interviews, however, were not saved in a standard format as each interview was different, which is likely to be the case with semi-structured interviews. Additionally, a daily field report was made based on the notes from my field notebook, and then as I reflected on this daily report, additional thoughts and ideas and follow-up activities were also written down.

2.3.3 Limitations of the Research

An important limitation of this research is the fact that the satellite images I analyzed are of the 2004/2005 season. Due to limitations in availability, quality, and finances, this was the most recent season I could find suitable images for. As I quantified the ET_a, biomass, yield production, and CWP for this specific season, I had to make sure to ask the interviewees to think specifically about their circumstances back in 2004/2005 in order for it to correspond to my maps. However, I made sure to also focus on changes that might have happened between 2005 and present, and I have tried to incorporate these in my report.

Reference	Organization	Position
AKW	Akwandze	Loans Manager
BT-1	Booker Tate	Project Manager
BT-2	Booker Tate	Agriculturist
CG-1	CANEGROWERS	Grower Affairs Manager
CG-2	CANEGROWERS	Regional Economic Advisor
DALA-1	DALA	Extension Officer
DALA-2	DALA	Director Technology Research and Development
DB[1]	Duplessis & Burger	Former Engineer
DoA-1	DoA	Chief Engineer
DoA-2	DoA	Former Head of Extension
DoA-3[2]	DoA	Former Extension Officer
DWAF-1[3]	DWAF	Former Water Resources Manager
DWAF-2[4]	DWAF	Former Depute Director Water Quality
END[1]	Endecon	Engineer
ICMA-1[3]	ICMA	Executive Manager Water Resources Planning
ICMA-2[4]	ICMA	Executive Manager Water Use
KOBWA-1	KOBWA	Systems Analyst Water Resources
KRIB-1	Komati River IB	Chairman
KRIB-2[5]	Komati River IB	Board Member
LB-1	LandBank	Agricultural Economist
LB-2	LandBank	Head of Operations
LIB-1	Lomati IB	Chairman
LIB-2[6]	Lomati IB	Former Chairman
LIB-3[5]	Komati IB	Board Member
PA[2]	PietAgri	Private Consultant Restructuring Programme
SASRI-1	SASRI	Extension Officer
SASRI-2	SASRI	Extension Officer
TA	Tribal Authority	Tribal Office Chairperson
TSB-1	TSB	Extension Manager of Small Scale Growers
TSB-2	TSB	Extension Manager of Commercial Growers
TSB-3[6]	TSB	General Manager Cane Supply
TSB-4[5]	TSB	Irrigation and Water Engineer
TSB-5	TSB	Inbound Supply Chain Manager
WW	Wwater	Private Consultant for the Komati and Lomati IBs

Table 2.1: Stakeholder Interview Matrix.

TSB was very helpful in sharing their yield data with me. They provided me with their entire GIS database which had information on field locations, plot sizes, plot outlines, grower names, crop varieties, harvesting dates, water sources, yield (ton/ha) and RV% for the years 2004-2007. Staff of the ICMA also provided me with additional GIS files, and recent DWAF articles. Finding literature about the water issues within the research area was difficult however. Therefore, I had to really rely on people’s own perceptions and knowledge on the area and the issues at stake. This made it difficult to obtain factual information, keeping in mind that different perceptions on reality always exist. There seemed to be a lack of transparent and reliable figures on water use in the Lower Komati, as well as a high level of uncertainty over the exact cultivated and irrigated area in the sub-catchment and the exact amount of water used by the irrigation sector. Different sources conflicted each other. There seemed to be a lack of integration of information between the DWAF head office in Pretoria and the DWAF regional office in Nelpruit. Moreover, DWAF seemed reluctant to share information with, and delegate powers to, the ICMA. Therefore, the data that was shared with me was often outdated.

I also had trouble finding a reliable and neutral interpreter. This led to some delay at the beginning of my time in South Africa. However, once this problem was solved, everything went very smoothly. Some smallholder farmers were reluctant to talk me: another "white scientist" who was "attracted to their problems like flies are attracted to a wound". They didn't want to waste their time talking, talking, talking, talking, and then not having their problems solved afterwards. However, most farmers were very willing in talking to a student from the Netherlands and gave me a wealth of information. It was clear that some farmers were afraid to give any critique on the different stakeholders, afraid of repercussions. But after explaining I was working for myself, and not for TSB, DWAF, or any other organization, and that all interviews would be kept anonymous, they usually loosened up. My interpreter helped me tremendously by making small talk with the farmers in their own language, and casually digging deeper into certain issues after the interviews, during the breaks or just in passing.

After having set out the structure of this report in the conceptual framework, which formed the basis for the research question and methodology, the next chapter will start with identifying areas of high and low ET_a, biomass, yield production and CWP. It will then continue with finding crop-physiological and socio-economical reasons for this diversity among farmers.

CHAPTER 3: EXPLORING THE DIVERSITY OF EVAPOTRANSPIRATION, BIOMASS, YIELD PRODUCTION AND CROP WATER PRODUCTIVITY IN THE LOWER KOMATI

3.1 IDENTIFYING AREAS OF HIGH AND LOW EVAPOTRANSPIRATION, BIOMASS, YIELD PRODUCTION, AND CROP WATER PRODUCTIVITY

This chapter will present maps of evapotranspiration (ET_a), biomass, yield production and crop water productivity (CWP), as they give an overview of the diversity of these parameters in the Lower Komati sub-catchment. In addition, the crop-physiological and socio-economical reasons for this diversity among emerging and commercial farmers will be explored. Background information on calculations and the here presented graphs can be found in the Technical Annex.

3.1.1 Primary Results

The Landsat study calculated the ET_a and biomass produced for sugarcane for the Lower Komati sub-catchment. The season 2004/2005 was selected for analysis, and nine Landsat images were used in the SEBAL application.

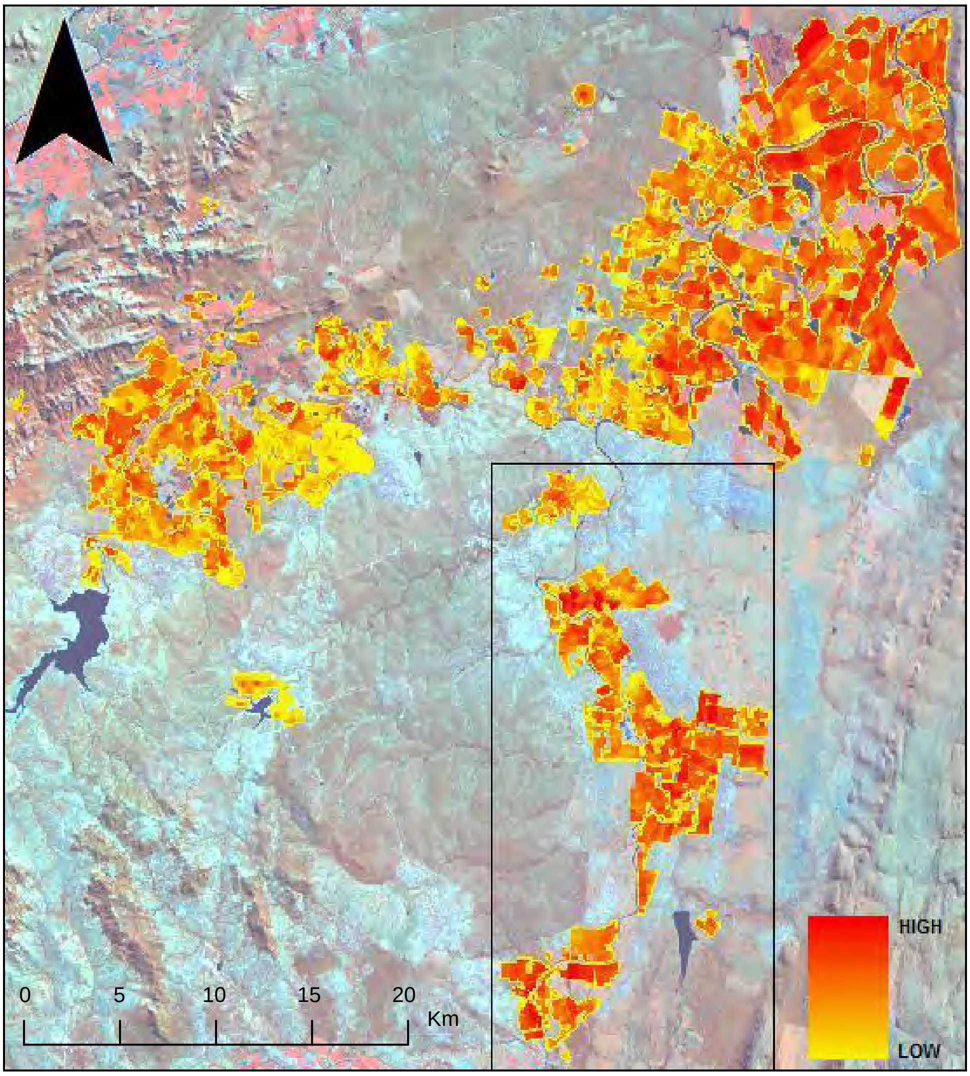


Figure 3.1: Seasonal ET_a with high resolution for Landsat 168-78 for the 2004/2005 season. Red is high ET_a, yellow is low ET_a.

The application of SEBAL to Landsat images resulted in two major primary outputs. The actual consumed water, ET_a, was calculated based on the energy balance. The biomass production was calculated based on the NDVI and the available solar radiation. The total seasonal ET_a resulting from the Landsat study is shown in figure 3.1. The selection of agriculture between Swaziland and the convergence of the Komati and the Crocodile Rivers shows an area, of emerging small-scale farmers and commercial large scale farmers, in which individual sugarcane fields can be distinguished. Red colours show areas with high seasonal water consumption, while yellow colours show areas with low seasonal water consumption.

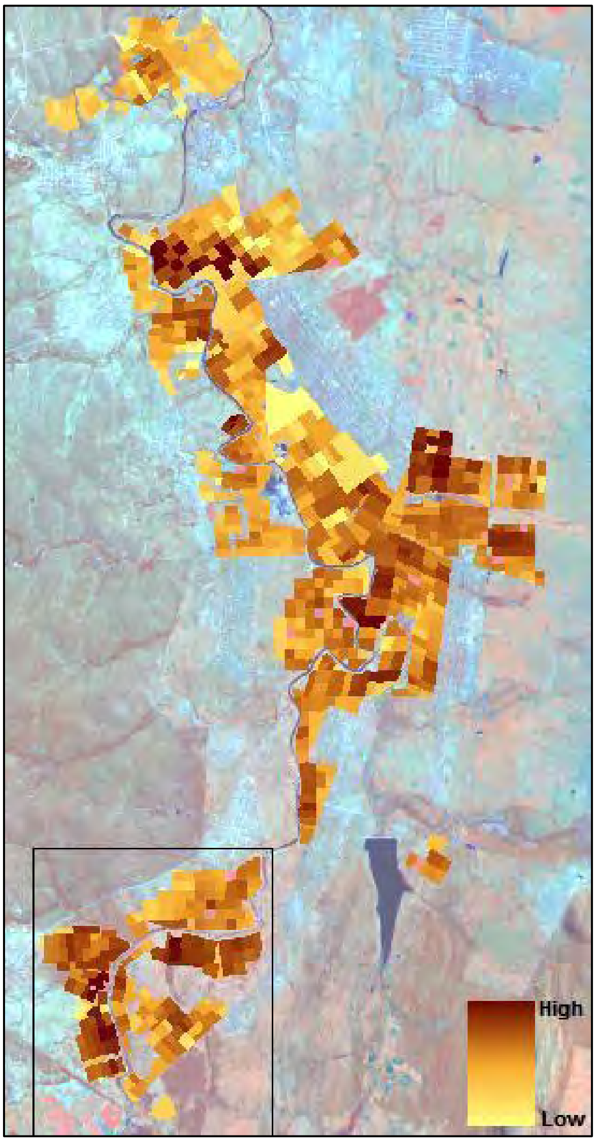


Figure 3.2: Sugarcane biomass production of emerging farmers. Dark brown is high, light brown is low production.

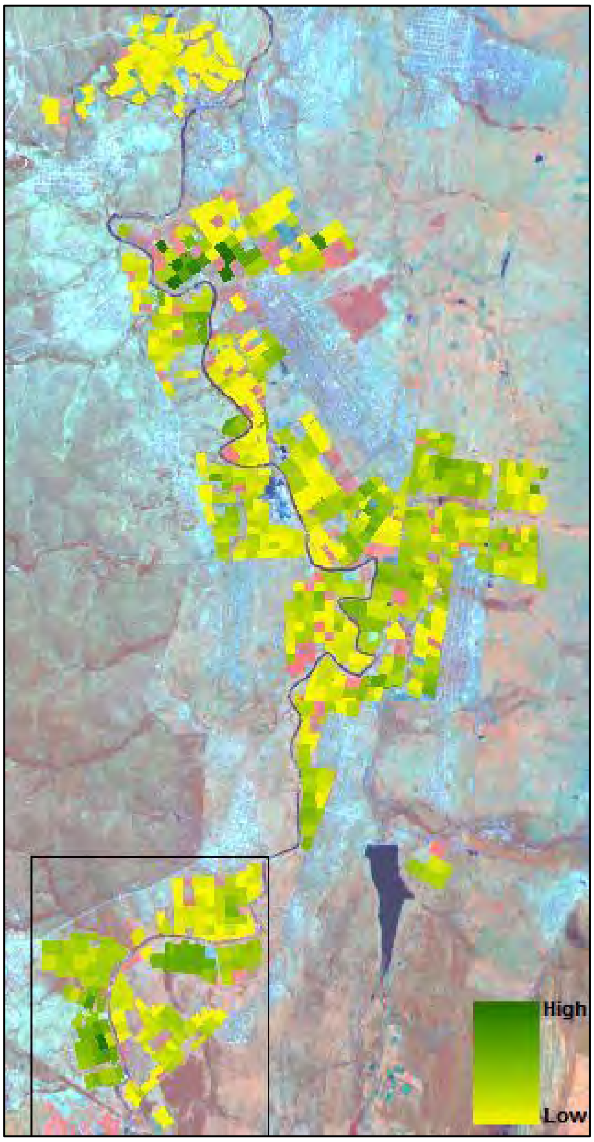


Figure 3.3: Sugarcane yield (TSB measured) of emerging farmers. Dark green is high, yellow is low production.

Looking at an area of emerging farmers, figure 3.2 shows the seasonal dry biomass production of irrigated sugarcane for the analyzed period. The dark brown areas are highly productive areas, while the light brown areas are areas of low production. Not surprisingly there is a visual match between figure 3.1 and figure 3.2. The red areas indicating high water consumption correspond to the dark brown areas indicating high biomass production as areas with high biomass production consume a lot of water. This is due to the linear correlation between ET_a and biomass as described in chapter 2. Figure 3.4 shows this correlation. The difference in slope between commercial (CF) and emerging farmers (EF) might indicate a lower overall soil fertility for the emerging farmers. This will be further explored later in this chapter. Note that the calculations within SEBAL for both products are independent of each other. ET_a and biomass are computed separately. Maps of the ET_a and the biomass production of all farmers can be found in Annex II.

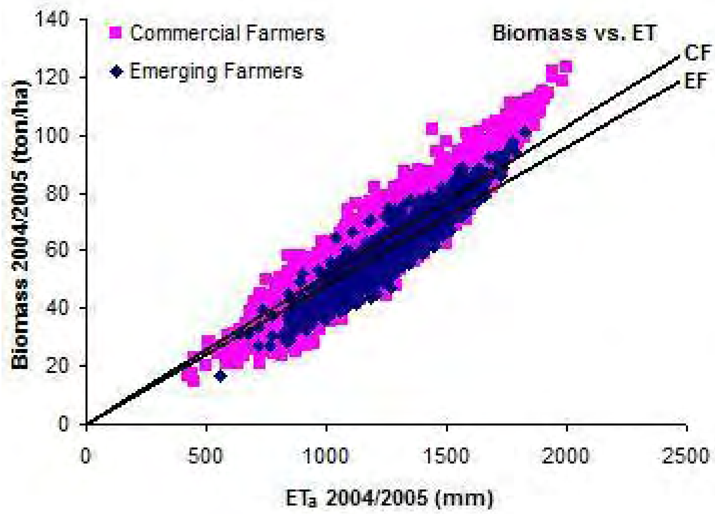


Figure 3.4: The linear correlation between ET_a and biomass of emerging and commercial farmers in 2004/2005.

3.1.2 Secondary Results

CWP indicates the crop production per unit water consumed. In order to calculate the CWP, the biomass production was converted to actual yield using literature values for the harvest index (69%) and moisture content (65%) of sugarcane (Bastiaanssen & Ali, 2003). This calculated yield was then compared to the actual measured yield (of harvested sugarcane) by TSB (see also the Technical Annex). As can be seen in figure 3.5, the measured yield values show a higher diversity compared to the yield values as calculated from biomass. This could be expected as calculation of yield from biomass uses mathematical models, while the measured yield depends on factors in the field that are not always known. In reality, the harvest index is not constant. The 69% harvest is affected by factors such as water stress, soil fertility, crop variety and crop disease. Similarly, the moisture content of sugarcane may vary per plot. Moreover, at the start of the growing season weeds may lead to an overestimation of biomass. Assuming that the TSB measured yield values are correct and depict the true yield production of sugarcane in the Lower Komati, it was decided to use these values for CWP calculation. Figure 3.3 shows the yield production for emerging farmers (as measured by TSB). Plots that did not harvest any sugar in the 2004/2005 season were given a zero value (no colour). For a complete yield map of all farmers see Annex II.

Figure 3.6 shows the CWP of sugarcane for three projects in the Lower Komati. The purple areas show areas of high crop production per unit water, while the light blue areas show areas of low crop production per unit water. A high amount of crop production per unit water consumed (high CWP) is an indication of efficient water use by the plant. It must be noted that this is not the same as the concept of irrigation efficiency, which is a measure of how well the water was delivered to the plant. The impacts of water control and distribution can be monitored in terms of productivity, indicating the potential for improved management where productivity is low, and the identification of good management where productivity is particularly high (Soppe *et al*., 2006). A number of plots in figure 3.6 do not have a value for

CWP. The first reason for this is that these plots did not produce any yield in the 2004/2005 season, leading to a CWP of zero. The second reason is that these fields (which are current sugarcane plots) were not identified as sugar in the 2004/2005 satellite image. The ET_a was not determined for these plots, and no value for CWP exists, as people only started growing sugar on these plots after 2005. For a map of the CWP of all farmers in the Lower Komati see Annex II.

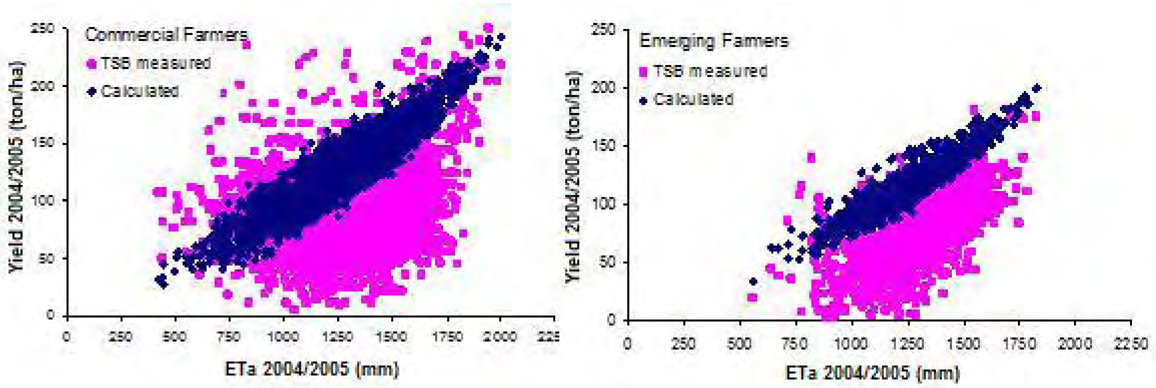


Figure 3.5: The relationship between ET_a and calculated and measured yield for commercial farmers (left) and the relationship between ET_a and calculated and measured yield for emerging farmers (right).

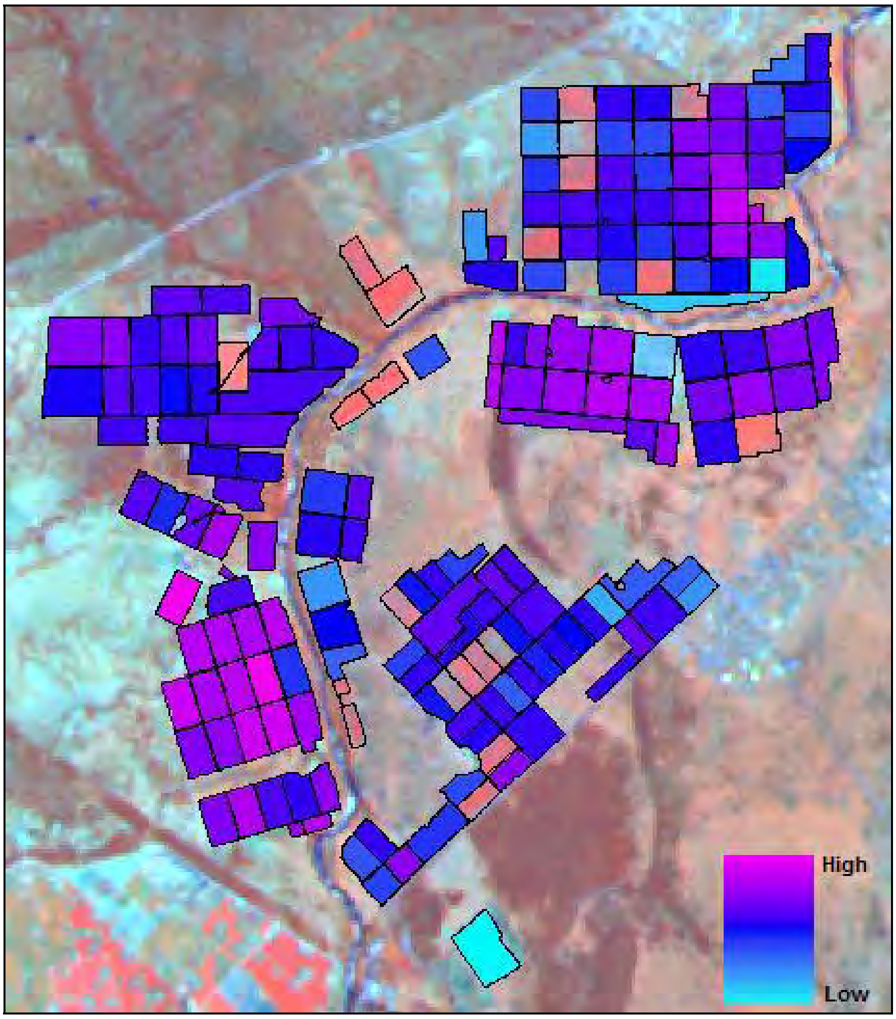


Figure 3.6: CWP for the individual sugarcane fields in Magudu, Sibange and Spoons 8. Purple is high CWP, blue is medium CWP, light blue is low CWP.

Although this paragraph mainly gives examples of the situation of emerging farmers, the maps in Annex II show that the situation of commercial farmers is similar when it comes to the diversity in ET_a, biomass, yield, and CWP. Both commercial and emerging farmers have areas of high and low ET_a, high and low biomass, high and low yield production, and high and low CWP.

N.B. It must be noted that the images used for analysis were taken on cloud free days or days with minimal cloud cover. As linear interpolation over time was used to calculate the total ET_a over the 2004/2005 season (see Technical Annex) there is a good possibility that the calculated values for ET_a are overestimating the actual values for ET_a as ET_a over cloudy periods is most likely less than the interpolated ET_a. However, as this research focuses on *relative* differences in values for ET_a, biomass, yield production and CWP between sugarcane plots, this is not a major limitation for this thesis. The next paragraphs will continue with finding reasons for the diversity among these four parameters.

3.2 EXPLORING THE DIVERSITY OF EVAPOTRANSPIRATION, BIOMASS, YIELD PRODUCTION AND CROP WATER PRODUCTIVITY FROM A CROP-PHYSIOLOGICAL PERSPECTIVE

Weather parameters, crop characteristics, management and environmental aspects are factors affecting evaporation and transpiration. It is generally accepted that transpiration of field crops is limited by either the supply of water to be evaporated or the supply of energy to provide the heat for vaporization of the water (De Wit, 1958). The principal weather parameters affecting evapotranspiration are radiation, air temperature, humidity and wind speed. The crop type, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields. Factors such as soil salinity, poor land fertility, limited applications of fertilizers, the presence of hard or impenetrable soil horizons, the absence of control of diseases and pests and poor soil management may limit crop development and reduce the evapotranspiration. Other factors to be considered when assessing evapotranspiration are ground cover, plant density and the soil water content. The effect of soil water content on evapotranspiration is conditioned primarily by the magnitude of the water deficit and the type of soil. On the other hand, too much water will result in waterlogging which might damage the root and limit root water uptake by inhibiting respiration. Additional consideration should be given to the range of management practices that act on the climatic and crop factors affecting the evapotranspiration process. Cultivation practices and the type of irrigation method can alter the microclimate, affect the crop characteristics or affect the wetting of the soil and crop surface (FAO, 1998). This paragraph will start with exploring crop-physiological factors influencing ET_a and biomass of sugarcane in the Lower Komati. In addition, the effect of these factors on yield production and CWP will be explored.

3.2.1 Climate

The Lower Komati is part of the ‘lucky’ one third of the country that receives over 500mm of rain per year. The other two thirds of the country receive less (PA, 2008). However, the sub-catchment is still considered a stressed basin, even after completion of the two dams. Ideally, sugarcane needs 1200 – 1500mm of water per year (PA, 2008; SASRI, 2008a; TSB-3, 2008), and the broad perception is that there is a slight deficit in the Lower Komati (BT-2, 2008; ICMA-1, 2008; PA, 2008; TSB-3, 2008). Over the past years the water stress and drought may have contributed to the general decline of average yield production for sugarcane farmers in the Lower Komati (TSB, 2004; TSB, 2005; TSB, 2006; TSB, 2007).

The Lower Komati is characterized by flat to gently undulating topography. Because of the surrounding mountains, there are several micro-climatic regions. Temperature and rainfall vary from region to region: while Malelane receives around 500mm rainfall per year, Kaalrug, which is 17km down the road, receives around 750mm/year (SASRI, 2008a). In 2004, DWAF and DFID (Department for International Development) delimitated homogeneous climate zones in the Inkomati WMA. These zones were mainly based on Mean Annual Precipitation (MAP) and average rainfall, and then further augmented with other characteristic information such as elevation, slope and temperature. The methodology is outlined in the Guide (DWAF/DFID, 2004). Four climate zones as demarcated by DWAF and DFID are relevant for this research, and will be used for analysis (see figure 3.7). The eastern zone of the sub-catchment, around and south of Komatipoort, has a relatively low altitude (around and below 200m.a.s.l.) compared to the rest of the sub-catchment (DWAF, 2000). Rainfall is lower here, and temperatures tend to be higher (SASRI, 2008a). Moving west, towards Malelane, the area has a higher altitude, around 300m.a.s.l (DWAF, 2000), corresponding to a slightly cooler temperature and a higher rainfall (SASRI, 2008a).

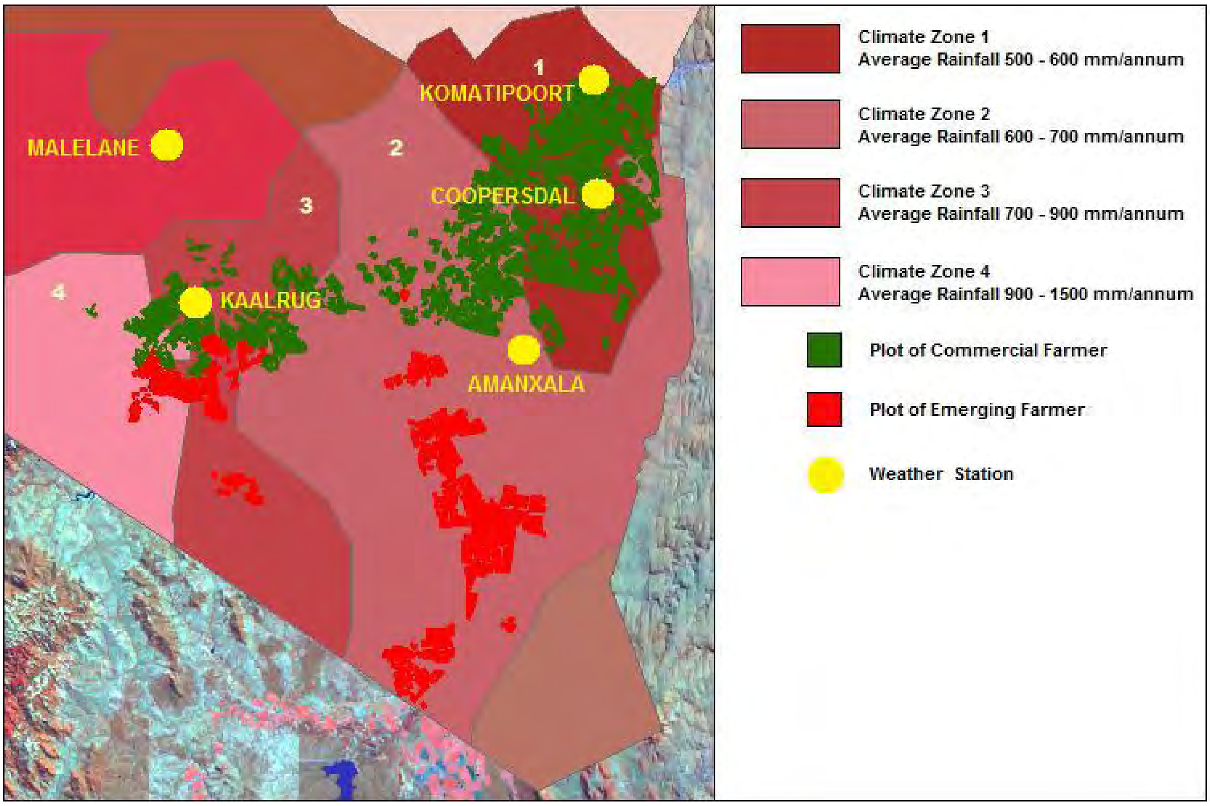


Figure 3.7: Climate Zones (based on MAP and average rainfall) in the Lower Komati (DWAF/DFID, 2004).

Besides rainfall, the evaporation power of the atmosphere (ET_o) influences ET_a. Evaporation of water requires energy. Climatic factors determining evapotranspiration are those that provide energy for vaporization and remove water vapour from the evaporating surface. The four main climatic factors affecting evapotranspiration are solar radiation, air temperature, air humidity and wind speed (FAO, 1998). Five weather stations in the area provide data on these four parameters of which four weather stations are of interest: Komatipoort and Coopersdal in climate zone 1, Amanxala in climate zone 2, and Kaalrug in climate zone 3. Table 3.1 below shows average values for radiation, temperature, relative humidity and wind speed of the four weather stations for the 2004/2005 season. Temperatures all over the catchment seem to be in the same range, although one weather station may not be enough to truly reflect these differences. Long term data (SASRI, 2008a), however, indicates that temperatures tend to be higher in the East (climate zone 1), and lower in the West (climate zone 3-4). Paired with the highest radiation values and lowest humidity values for climate zone 1 it is expected that this zone will have the highest ET_o. A relatively high wind speed contributes to this, although wind speed at Komatipoort is lower which means that this section may have a slightly lower ET_o. The ET_o values for climate zones 2 and 3 are expected to be lower than those for climate zone 1. Comparing these two zones, temperature and windspeed are higher for climate zone 2, while the humidity is lower. However, radiation is higher for climate zone 3. Higher values for ET_o are expected for climate zone 2, but differences with climate zone 3 may be small. There is no weather station in climate zone 4, but it is assumed that the trend will continue, meaning that climate zone 4 will have the lowest ET_o. It must be noted, however, that the Lower Komati is a relatively small area. The sub-catchment may be too small to have distinctly different climatic zones, meaning that these zones might be too similar to really have an effect on ET_o.

Climate Zone	Weather Station	Rad (MJ/m^2)	T_{mean} (^oC)	RH (%)	Wind Speed (km/day)
1	**Komatipoort**	19.6	22.9	67.1	75.8
1	**Coopersdal**	19.0	23.2	59.8	134.1
2	**Amanxala**	17.7	23.0	69.8	134.3
3	**Kaalrug**	18.1	22.7	69.9	103.1

Table 3.1: Average values for radiation, mean temperature, relative humidity and wind speed of four weather stations for the 2004/2005 season (SASRI, 2008a).

3.2.2 Soil

When it comes to soil fertility, soils with a clay content greater than 15%, a pH of ± 7, an effective rooting depth of greater than 500mm, without salinity/sodicity problems and impervious layers, are generally considered suitable for growing sugarcane (BT-2, 2008). In addition, TSB claims that soils must be able to support a constant annual yield of 100ton/ha on a 10 year ratoon cycle in order for them to be considered suitable (BT-2, 2008; TSB-3, 2008). Using the soil description maps of paragraph 1.3.2.3, three soil classes, based on the clay content of the top soil, were identified for analysis (figure 3.8). A finer textured soil, with a higher clay content (soil class 1) will have a higher water retention capacity compared to a coarser, sandier soil with a lower clay content (soil class 3). Moreover, soils with a higher clay content have a higher fertility than soils with a lower clay content.

The commercial farmers who farm around Komatipoort have good, high potential soils, which are extremely fertile. These are mostly black soils (e.g. Arcadia, Bonheim and Rensburg) with a clay content of 50-70% (BT-2, 2008). This area is known for producing the highest sugarcane yields in South Africa, with TenBosch Farm being the number one farm for sugarcane production in South Africa (PA, 2008; TSB-3, 2008). This high potential soil line at the east of the catchment continues southwards near the Mozambican border. Moving west, closer to the confluence with the Lomati River, soils become less fertile, and are of low to medium potential. Some soils in this area are extremely poor, and open areas have been eroded by pressure of cattle and community. The soils in this area vary from red soils (e.g. Hutton and Glenrosa) with a clay content of 15-35% to sandy soils (e.g. Glenrosa) with a clay content less than 15% (BT-2, 2008). Further to the west, the commercial farmers along the

Lomati River farm on a mix of fertile, medium, and marginal soils with different clay contents.

The emerging farmers seem to be disadvantaged when it comes to soil type. Most of the projects are situated in soil classes 2 and 3. The NIEP Phase I projects, which include Figtree A, Figtree B, Shinyokana, Lugedlane, Ngogolo and Buffelspruit (see Annex I) were established in 1988/1989. These first 1500ha were all established on the best available soils as engineers selected them based on fertility and proximity to water. The rest of the projects (6000ha) were established between 1994 and 1998 on the 'leftover soils', which are a mix of soils ranging from fertile to marginal to sandy and rocky. The projects on the Lomati River seem to have worse soils than the projects on the Komati River with Boschfontein I and II being extremely sandy. Four of the Phase II projects ('the seven projects'), Mzinti, Phiva, Langeloop II and Vlakbult were established on very marginal soils, which mostly contain sand and rocks. On top of that, Mzinti and Phiva struggle with saline soils. Ntunda and Magudu are located in soil class 2, but are in the bottom range when it comes to clay content.

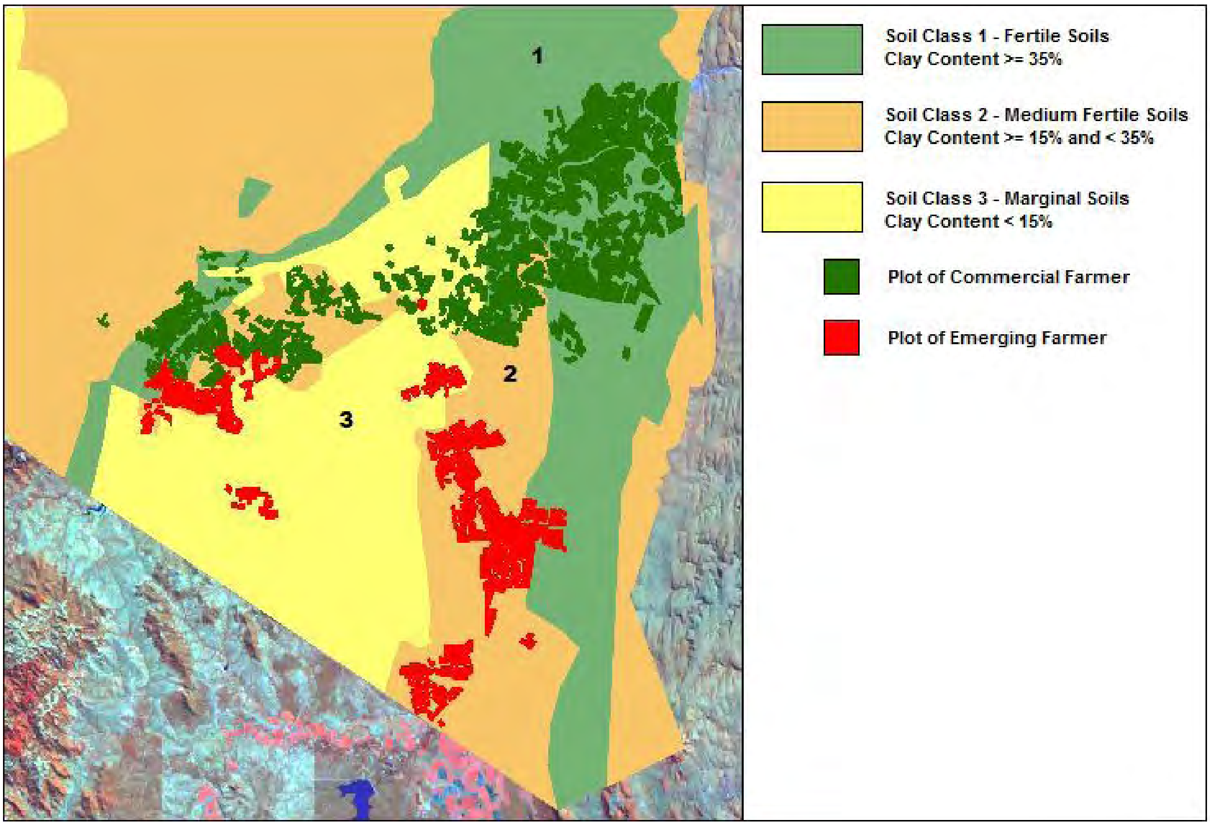


Figure 3.8: Soil Classes (based on clay content of the top soil) in the Lower Komati (Department of Environment and Tourism, 2008).

Sikhwahlane (soil class 2) is the Phase II project with the highest fertility. 50% of Phiva, 60% of Ntunda, 30% of Walda, 30% of Mbunu B, 30% of Mzinti, 40% of Langeloop II, 50% of Boschfontein, 60% of Schoemansdal and Middelplaas will generally be considered as unsustainable in the long term due to low clay content, as well as some areas with salinity/sodicity problems (BT-2, 2008).

3.2.3 Analysis of the Effect of Climate and Soil on ET_a and Biomass

In order to explore the effect of climate and soil fertility on ET_a and biomass, eleven new climate/soil classes were established based on the four different climate zones, the three different soil classes and the presence of either emerging farmers, commercial farmers or both (table 3.1). Of these eleven new classes, classes 12 and 43 were disregarded, as they had an amount of pixels less than 1% of the total, and were believed to not contribute significantly towards the average values of ET_a, biomass, yield production and CWP.

Class	Climate Zone	Soil Class	Comments
11	1	1	Commercial farmers only
12	1	2	Commercial farmers only, pixel count < 1%
13	1	3	Non existent
21	2	1	Emerging and commercial farmers
22	2	2	Emerging and commercial farmers
23	2	3	Emerging and commercial farmers
31	3	1	Commercial farmers only
32	3	2	Emerging and commercial farmers
33	3	3	Emerging and commercial farmers
41	4	1	Emerging and commercial farmers
42	4	2	Emerging and commercial farmers
43	4	3	Emerging farmers only, pixel count < 1%

Table 3.2: Twelve climate/soil classes.

When it comes to climate, the two main factors influencing ET_a are rainfall and ET_o. The requirements of the irrigation system depend on these two factors. High ET_o indicates that more water is needed more frequently. Similarly, low rainfall means that more water is needed more frequently. When it comes to the soil, the clay content is of interest. A soil with a higher retention capacity will need less frequent applications of water while a sandy soil will need a higher frequency of water applications.

Climate	**1**	**2**			**3**			**4**	
ET_o	High	Medium-High			Medium-Low			Low	
Rainfall	Low	Medium-Low			Medium-High			High	
Expected ET_a	High	Medium-High			Medium-Low			Low	
Soils	**1**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**
Retention	High	High	Medium	Poor	High	Medium	Poor	High	Medium
CLASS	**11**	**21**	**22**	**23**	**31**	**32**	**33**	**41**	**42**

Table 3.3: Conditions of ET_o, rainfall and retention capacity of the soil within nine climate/soil classes.

Table 3.3 gives an overview of the state of the nine different climate/soil classes related to ET_o, rainfall and retention capacity of the soil. Climate zone 1 has high ET_o and low rainfall. Effective rainfall in this zone is low. As ET_o is high, irrigation requirements are high, which is in turn related to water availability (allocations). The expected average ET_a for this climate zone is thus high. There is only one soil class within climate zone 1. This soil has a high retention capacity. This means that the soil is less sensitive to irrigation breakdowns, and that frequency of irrigation should be low. The CWP is related to the availability of irrigation water, and also depends on the irrigation system. Moving West, rainfall is higher while ET_o is lower for climate zone 2. This means that effective rainfall is higher, and irrigation requirements are lower compared to climate zone 1. The expected average ET_a for this zone is thus lower. Climate zone 2 has three different soil classes. Marginal soils are very sensitive to irrigation frequency. Therefore, the frequency of irrigation should be highest in class 23, and lowest in class 21. The range of ET_a is expected to be largest for class 23 and lowest for class 21. This is because some farmers on the marginal soils will be able to improve ET_a by using adequate irrigation systems. On the other hand, a certain amount of farmers without adequate irrigation systems will suffer from the marginal soils, which results in lower values for ET_a. Moving on to climate zone 3, rainfall is even higher while ET_o is going down. This means that the expected average ET_a for this zone is lower compared to climate zone 2. Similarly to climate zone 2, the frequency of irrigation should be highest in class 33 and lowest in class 31. The range of ET_a is expected to be largest for class 33 and lowest for class 31, again depending on the irrigation systems of the farmers. Finally, average ET_a for climate zone 4 is expected to be lowest, due to the highest rainfall, and lowest values for ET_o. Irrigation requirements are lowest for this zone. There are no marginal soils (class 3) in this area. Irrigation frequency for class 42 should be higher than for class 41. The range of ET_a is expected to be larger for class 42 and lower for class 41.

Plotting histograms of the values for ET_a, biomass, yield production and CWP of the final nine classes gives an insight into the values and spread of these factors, and allows for comparison and analysis of the influence of climate and soil type respectively. The y-axes of the histograms represent the normalized pixel count. When reading a histogram it must be pointed out that outliers (the tail) on either side of the histogram may represent an error in calculations related to possible boundary effects. Pixels for temperature have a lower resolution than pixels for NDVI (Normalized Difference Vegetation Index) and albedo. Especially at the borders of a plot this difference in resolution may result in errors when a temperature pixel calculates an average value using parts of the land outside the plot boundary. Values with an abnormal high amount of pixels may represent a local problem such as a water puddle. More likely, however, this high amount of pixels represents an error in calculation as well. A high amount of pixels for a certain value is usually related to different layers within a satellite image not overlapping precisely. To counter for this effect, values with an extremely high pixel count will be disregarded.

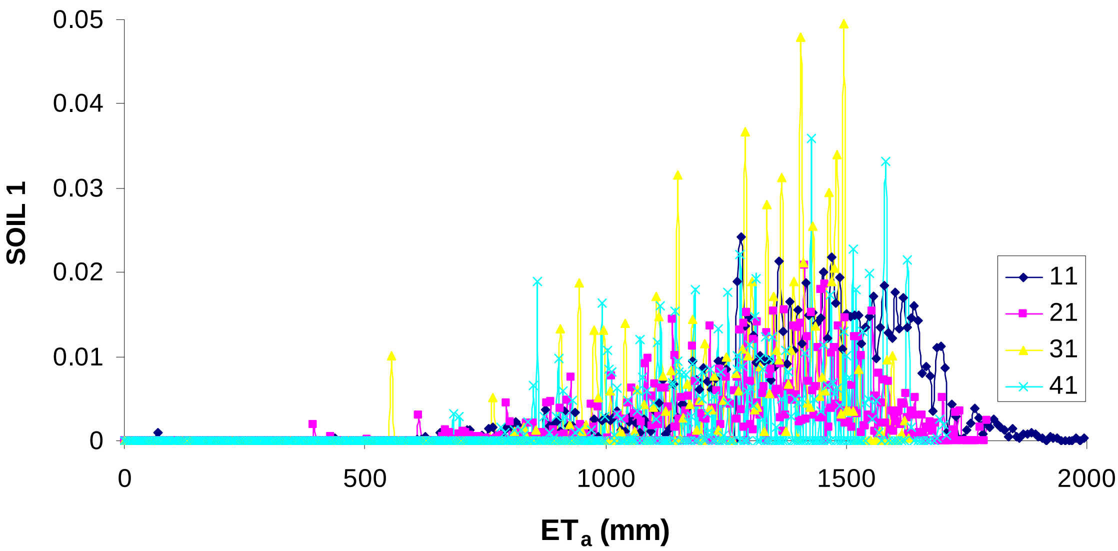


Figure 3.9: Histogram showing the influence of climate on values of ET_a within soil class 1.

To explore the influence of climate on ET_a and biomass, the values for ET_a and biomass of four different climate classes within one soil class were plotted in a histogram (figure 3.9 shows an example for soil class 1). To explore the influence of soil class on ET_a and biomass, the values for ET_a and biomass of three different soil classes within one climate zone were plotted in a histogram (figure 3.10 shows an example for climate zone 2). The rest of the histograms can be found in Annex III-A. Besides the shape of the histograms, the 20% values (20% of the farmers are below this value) and the 80% values (20% of the farmers are above this value) are important for analysis, as well as the median (50%) value. The median value was chosen over the average value, as the average value may include extremes. Comparing the 80% and 20% values to the median gives an insight into the position of successful and unsuccessfull farmers (see figure 3.11).

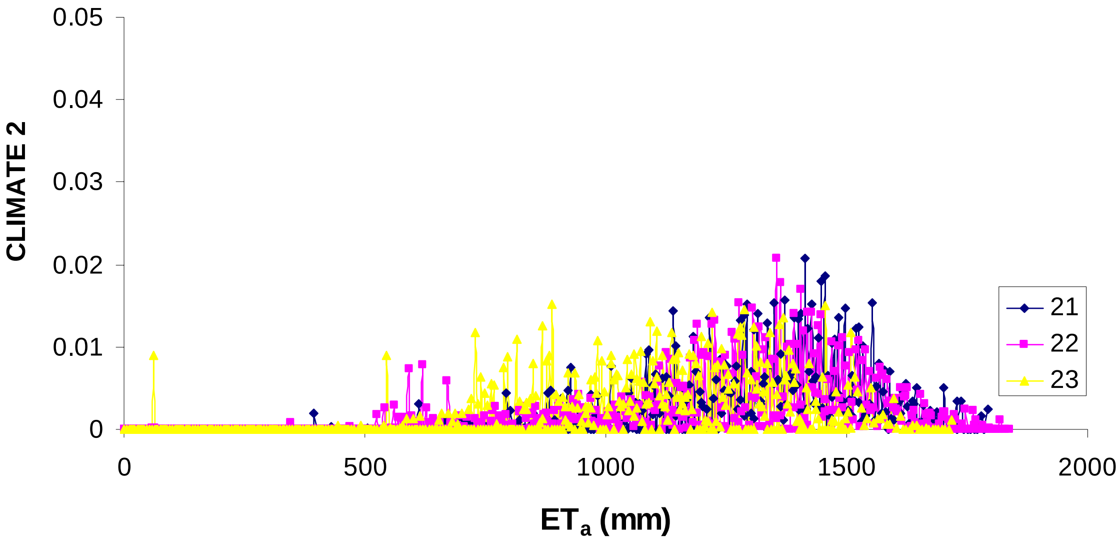


Figure 3.10: Histogram showing the influence of soil on values of ET_a within climate zone 2.

Both climate and soil fertility affect ET_a and biomass to some extent. As expected, median values for ET_a and biomass are highest for climate zone 1, lower for climate zone 2, and lowest for climate zone 3. This can also be seen in the histograms as values for climate zone 1 are shifted towards the right along the x-ax. However, this effect can only be assessed for soil class 1. The difference in ET_a and biomass between climate zones 2 and 3 is clear in the histograms for soil class 1 and 2. As the climate gets cooler and wetter (zone 3), there is a shift along the x-axes towards lower values for ET_a and biomass. This effect, however, cannot be seen within soil class 3. For climate zone 4, median values for ET_a and biomass are higher compared to climate zone 3, which was not expected. Moreover, the histograms do not show a clear influence of climate or shift along the x-axes. These observations indicate that climate does have some influence on ET_a and biomass in the Lower Komati, especially in the first three climate zones. However, the influence of climate on ET_a and biomass in zone 4 is not as expected. As the Lower Komati is a relatively small area, the sub-catchment may be too small to have distinctly different climatic zones. Differences between climate zones 3 and 4 seem to be especially small. Climate may therefore not be a good indicator for ET_a in this specific area.

Soil class seems to have a larger and more consequent effect on ET_a and biomass. Within each climate zone, median values for ET_a and biomass are highest in soil class 1, lower in soil class 2, and lowest in soil class 3. This indicates that, overall, farmers in the marginal soil classes have more trouble applying irrigation water timely and adequately than farmers in the more fertile soil classes. This effect can also be seen in the histograms. Especially for climate zones 2 and 4, a shift in values left along the x-axes is evident from soils with a high clay content to soils with a low clay content. This effect can also be seen for climate zone 3, albeit less clearly. Looking at the range of values of ET_a and biomass within each climate zone, the range in values becomes larger when the soil becomes more marginal. This indicates that part of the farmers on marginal soils have found ways to adequately apply irrigation water (high values

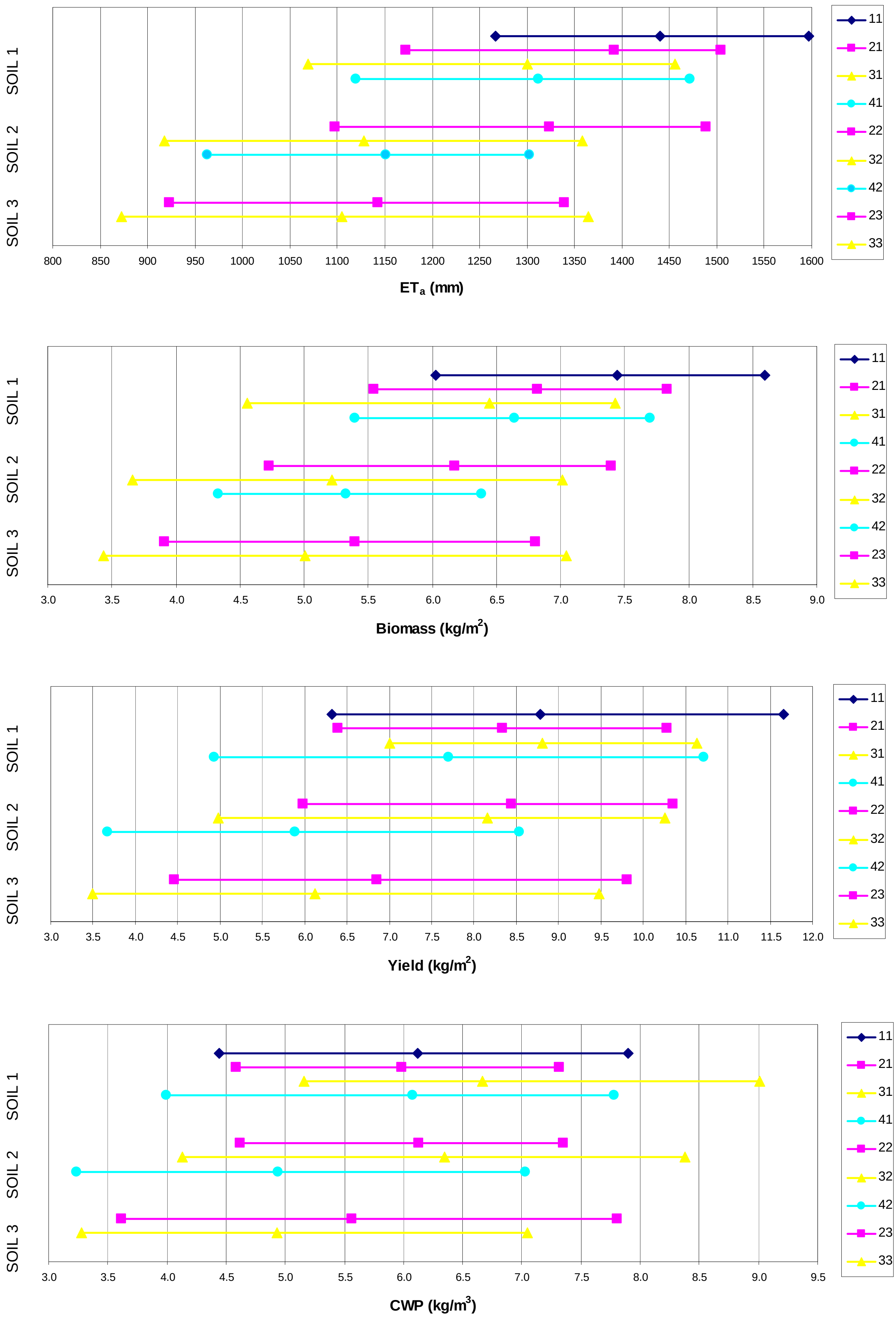


Figure 3.11: Graphs showing the range of values of ETa, biomass, yield production and CWP per climate zone and soil class compared to the median.

for ET_a and biomass). However, another part of these farmers have failed in applying appropriate irrigation practices, which translates to low values for ET_a and biomass. The only exception is within climate zone 4, as the range is smaller for soil class 3, but the differences are small. Even so, values for ET_a and biomass still show a large spread along the x-axes, and there is still a great diversity in ET_a and biomass among the different farmers within a single soil class. It seems that the aspects of water quantity and soil fertility have to be further explored to explain for this diversity.

When it comes to yield production, climate has some effect on yield production as median values decrease from climate zone 1 to climate zone 4. However, an exception concerns the farmers in climate zone 3 (soil class 1) who are performing relatively well. The influence of soil class on yield production has a similar effect, with median yields becoming lower when the soil becomes more marginal, indicating that soil fertility is a constraint for optimal yield production. Here, there is also an exception as farmers in soil class 2 (climate zone 2) are performing relatively well. Looking at CWP, it is expected that median values are highest for climate zones 4 and 3, as these farmers have to deal with lower values for ET_a. However, the influence of climate on values for CWP is unclear, as farmers in climate zone 4 are performing similar to farmers in climate zones 1 and 2 (soil class 1). For soil class 2, farmers in climate zone 4 have the lowest median values for CWP. Moreover, farmers in climate zone 1 (soil class 1) have higher median values for CWP than farmers in climate zones 2 and 4. This indicates that climate is not influencing values for CWP. Soil, however, does seem to influence CWP of farmers. Median values for CWP decrease when the soil becomes less fertile. It seems that soil fertility is a constraint for CWP of farmers on marginal soils. This effect can be seen in the histograms as well, as there is a shift in values for CWP left along the x-axes as the soil becomes less fertile. It must be noted that there are only slight differences between classes 21 and 22, with the median CWP being slightly higher for class 22. Similar to the ET_a and biomass, the range of values for yield production and CWP tend to be larger when the soil becomes more marginal, except for climate zone 4. Again, the spread of values along the x-axes indicate that this diversity needs to be further explored. It must be noted that yield production and CWP do not depend on climate and soil alone. Management practices such as the applications of fertilizers and weed control influence yield production further.

3.2.4 Crop Variety

Besides the just discussed factors of climate and water retention of the soil, a third crop-physiological factor that may influence values for ET_a and biomass concerns the type of crop. Due to differences in albedo, crop height, aerodynamic properties, and leaf and stomata properties, the ET_a of different crops will vary (FAO, 1998). In this research, however, the type of crop is irrelevant, as a subset of sugarcane has been made, excluding all other crops. The maps in paragraph 3.1 represent the ET_a, biomass, yield production and CWP of sugarcane only. Crop variety however, can have an effect on yield production and CWP. The four main sugarcane varieties in the Lower Komati are N14, N19, N25 and N32 and these varieties have different characteristics. In general N19 is perceived to have a relatively low to moderate yield production, compared to a moderate yield production for N32, a high yield production for N14, and even higher yield production for N25. These four varieties may also react differently to different climatic factors, such as water quantity. In general, N14, N19 and N32 grow poorly during severe water stress and recover poorly afterwards. In this aspect N25 is doing better as it still grows moderately during water stress, and recovers faster afterwards. The different varieties also react differently to soil fertility as, for example, N19 is more tolerant to salinity than N14, N25 and N32 (SASRI, 2008b). Moreover, different varieties have different harvesting indices which will also influence yield production. N25 seems to be the best variety to choose when it comes to ton/ha. This is reflected by the average harvested yield of N25 for commercial and emerging farmers, as it is the highest among the four varieties (table 3.3) (TSB, 2005). N25 also has the advantage that it is suited to a range of soils varying from soils with high clay content to sandy soils (SASRI, 2008b).

Even with the high expected yields for N25, N19 is the most popular variety among farmers, especially among emerging farmers. Over 70% of the emerging farmers grow N19. These farmers are attracted by the high sucrose content of N19 compared to the other varieties (EF, 2008). Also, N19 is more tolerant to soils affected by salinity, and is resistant to smut. Moreover, high nitrogen (N) use efficiency indicates that a lower rate of N fertilizer can be applied (SASRI, 2008b). Due to these characteristics, N19 is often described as the poor farmers' variety. What is important here is the economic water productivity, which is related to the farming system.

Variety	Commercial Farmers	Emerging Farmers
N14	9.3	6.2
N19	8.0	7.6
N25	9.8	8.3
N32	9.6	6.9

Table 3.4: Average yields (kg/m^2) for the four main varieties for 2004/2005 (TSB, 2005).

As seen in the previous paragraph, the influence of soil fertility and water retention capacity on yield production and CWP is higher than the influence of climate. Therefore, the impact of soil fertility on the yields of N19 and N25 was further explored. Climate zones 2 and 3 were selected for analysis, as these two zones are represented by high pixel counts in all three soil classes. Again, histograms were plotted to help with analysis. These can be found in Annex III-B. Figure 3.12 shows the 20%, 50% and 80% values of yield production of N19 and N25 for both emerging and commercial farmers.

For commercial farmers, median yields of N25 are overall higher than the yields for N19 in climate zone 2. However, for climate zone 3 (soil classes 2 and 3) median yields are higher for N19. Only few emerging farmers (3%) grow N25, so it is difficult to assess the effect of variety on yield production for this group. However, median yields for N25 do seem to be higher in climate zone 3. Overall, N25 does seem to benefit yield production, but the actual effect of variety is unclear as other factors may also affect yield production (e.g. theft of irrigation equipment and management practices). Looking at N19 it appears that emerging farmers are more affected by soil type than commercial farmers. Yield production of emerging farmers decreases when the soil becomes less fertile (and less water retentive). This gives an indication that, compared to the commercial farmers, less emerging farmers have applied adequate irrigation practices to deal with marginal soils. Surprisingly, median yields for N25 are high for emerging farmers in climate zone 3, soil class 3. This reflects the suitability of N25 for marginal soils, but may also indicate that these specific farmers have acquired good management skills in order to achieve these high yields. The range in yield production values for these farmers is very high, indicating that a significant part of these farmers has found ways to improve yield while being on marginal soils. This may be due to adequate irrigation systems that can apply water more frequently or due to other aspects within the farming system, such as the application of fertilizers. However, this zone also houses farmers with very low yields who have failed to find ways to adjust their irrigation practices to the marginal soil type.

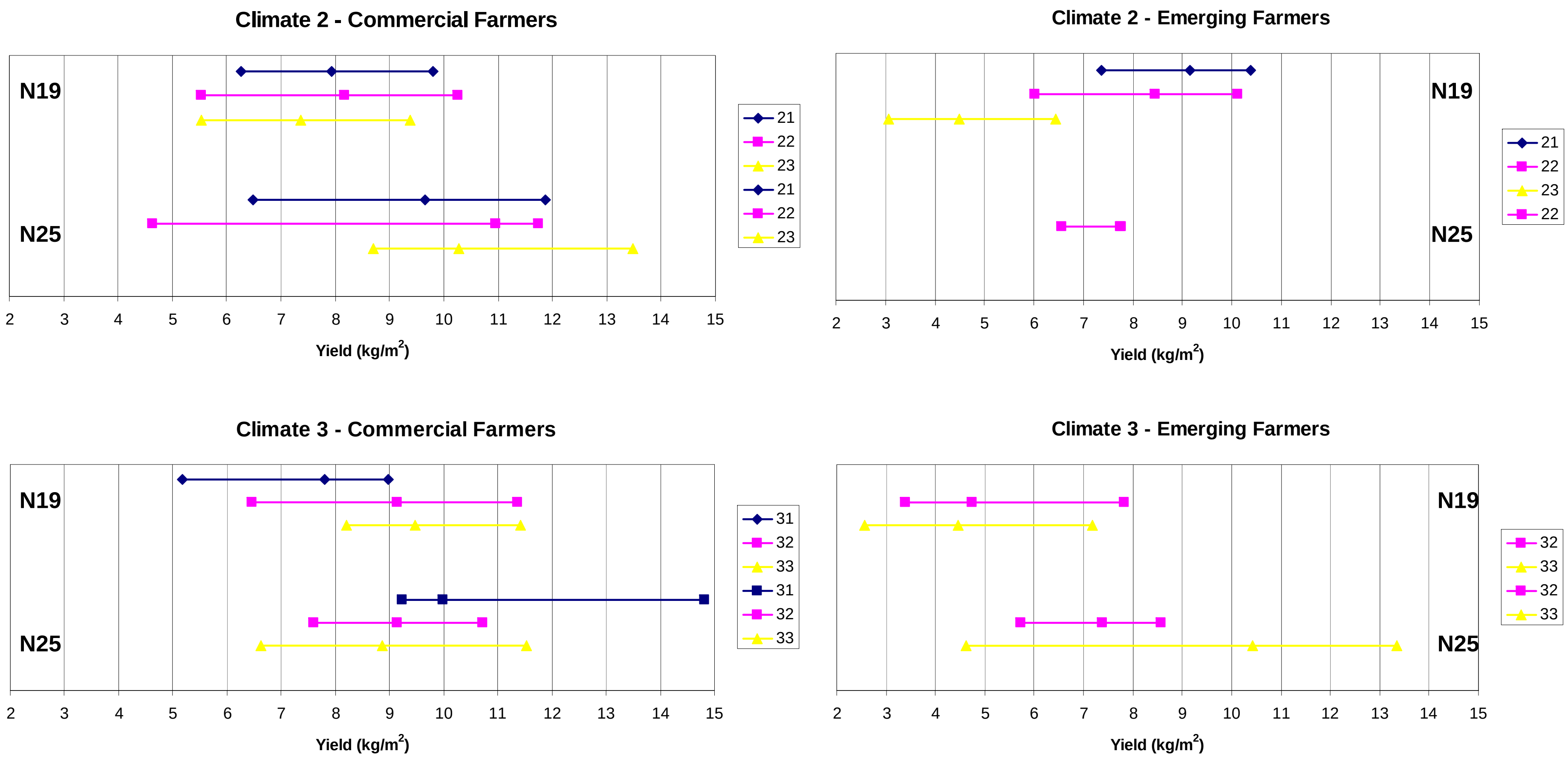


Figure 3.12: Graphs showing the range of values for yield production of N19 and N25 for both commercial and emerging farmers compared to the median.

So far, three important factors influencing ET_a, biomass, yield production and CWP in the Lower Komati have been described. However, water quantity and soil fertility are complex issues. Water quantity, for example, not only depends on rainfall, but also on irrigation. Soil fertility, which is related to the clay content of the soil, also depends on the application of fertilizers which is part of the farming system. Therefore, the socio-economic aspects of water quantity and soil fertility must not be overlooked. The spread of values for ET_a, biomass, yield production and CWP as can be seen along the x-axes of the histograms presented so far must thus be further explored within the socio-economic arena. The next paragraph will start with exploring the socio-economic aspects of water quantity, which might further influence values for ET_a, biomass, yield production and CWP. Chapter 4 will focus on the socio-economic aspects of soil fertility as related to the farming systems of farmers in the Lower Komati.

3.3 EXPLORING THE DIVERSITY OF EVAPOTRANSPIRATION, BIOMASS, YIELD PRODUCTION AND CROP WATER PRODUCTIVITY FROM A SOCIO-ECONOMIC PERSPECTIVE

The previous paragraph showed that diversity in ET_a, biomass, yield production, and CWP can be influenced by water quantity and soil fertility. Part of this diversity can be explained by crop-physiological factors as climate or the clay content of the soil. This paragraph will explore socio-economic factors related to water quantity that might influence the diversity in ET_a, biomass, yield, and CWP further. Besides water quantity, issues influencing this water quality, such as control, timing and precision, will be explored. This is particularly related to irrigation and irrigation efficiency. The issue of fertilizers is related to farming systems and will be explored in chapter 4.

3.3.1 Water Quantity

3.3.1.1 Rainfall

Ideally, the crop water requirement of sugarcane lies between 1200 and 1500mm per year (PA, 2008; SASRI, 2008a; TSB-3, 2008). Looking at the long term rainfall data for the Lower Komati (figure 3.13) it is clear that rainfall alone cannot care for this demand. Supplementary irrigation is essential, especially during the summer months, and this is why TSB sugar is 100% irrigated (TSB-4, 2008).

As planting dates of sugarcane vary from April to December all over the Lower Komati, the age of the crop varies all over the sub-catchment (TSB, 2008). Therefore, the ET_{cane} is plotted three times in figure 3.13. Once for the maximum (mid-season) crop water requirement (k_c = 1.25), once for the late-season water requirement (k_c = 0.75), and once for the initial crop water requirement (k_c = 0.40). These k_c factors were taken from literature (FAO, 1998). Figure 3.13 shows that even in times of minimum crop water requirements there is still a water deficit from, roughly, April to October.

Looking at the long term weather data of the weather stations in the Lower Komati, rainfall supposedly contributes around 650mm of water per year to the sub-catchment (SASRI, 2008a). However, due to the drought of the past years, this amount may be significantly lower over individual years. During the 2004/2005 season, for example, total rainfall measured only 419mm (SASRI, 2008a). Figure 3.14 shows the rainfall data for the 2004/2005 season plotted against the reference ET_o and the crop water requirement for cane. With a growing season of twelve months, three scenarios are depicted in figure 3.14. Scenario 1 concerns a growing season from April to April, scenario 2 from July to July and scenario 3 from October to October.

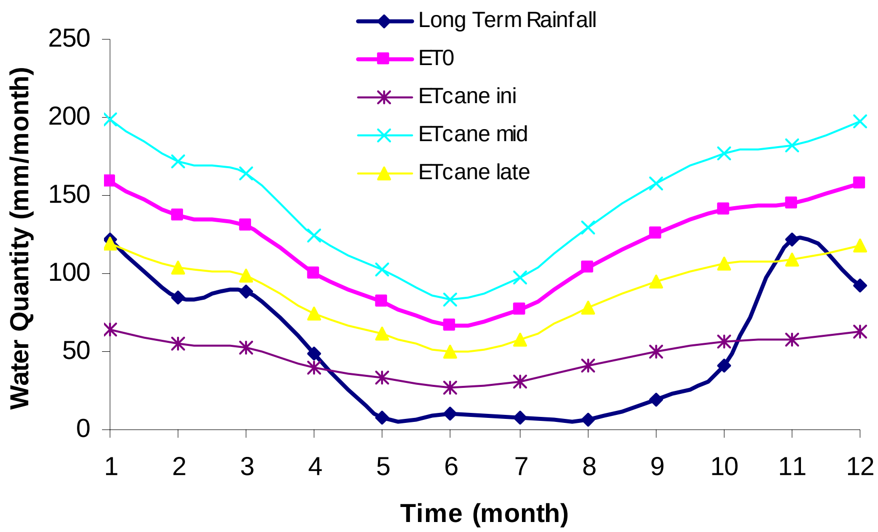


Figure 3.13: Long term mean data for rainfall, ET_o and ET_{cane} (SASRI, 2008a).

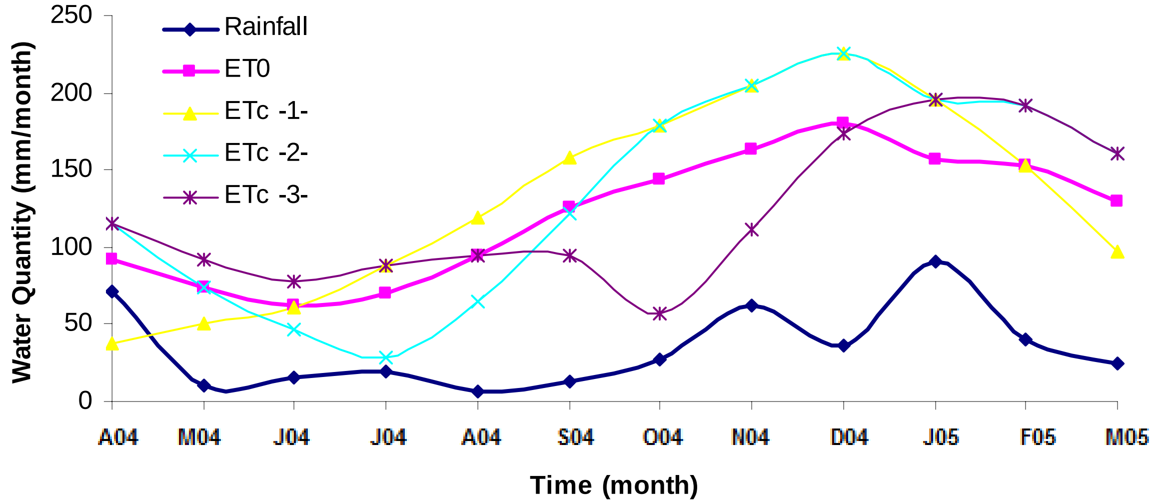


Figure 3.14: Rainfall and ET_o values for the 2004/2005 season (SASRI, 2008a). Three different scenarios for crop water requirements (ET_c) are plotted against the rainfall and ET_o.

3.3.1.2 Irrigation

It is clear that supplementary irrigation is essential for growing sugarcane. Looking at the 2004/2005 season, rainfall contributed 419mm to the crop water requirement of sugarcane (SASRI, 2008a). With a crop water requirement of 1200 to 1500mm per year (PA, 2008; SASRI, 2008a; TSB-3, 2008), the shortage had to be supplemented by irrigation water. Water quantity of irrigation water depends on water available in the Komati and Lomati Rivers, and is related to water allocations and water restrictions.

Water Allocations and Restrictions

What first springs to mind when looking at the water allocations in the Lower Komati is the fact that both rivers have different water allocations. Farmers on the Komati River receive 9,950m^3/ha (995mm) per year, while farmers on the Lomati River receive 8,500m^3/ha (850mm) per year (LIB-1, 2008). This is because the allocations were decided back in the 1980s when farmers on the Lomati River were mostly growing vegetables. The Irrigation Board (IB) thus based its water allocations on the crop water requirement of vegetables. The farmers on the Komati River were mostly growing bananas, and received a larger allocation (ICMA-1, 2008). Over the years, most farmers have changed to producing sugar, while the allocations have stayed the same. The IB has raised these issues with the Department of Water Affairs and Forestry (DWAF), but DWAF has said not to change any allocations until after the compulsory licensing process (DWAF-1, 2008). This in turn leads to the IBs accusing DWAF of refusing to get involved with politics (LIB-1, 2008; WW, 2008). With a rainfall of 419mm for 2004/2005, and a water allocation of 995mm and 850mm for the Komati and Lomati Rivers respectively, farmers theoretically had access to 1269 to 1414mm of water during the 2004/2005 season which should be sufficient for growing sugarcane, with the farmers on the Komati River having a slight advantage.

During times of drought, the Komati Basin Water Authority (KOBWA) puts water restrictions into place, reducing the actual water allocation for the farmer. For the past five seasons (which go from April 1st to March 31st) water has been restricted for the farmers in the Lower Komati. Currently (2008) all farmers are restricted by 25%, having access to 75% of their allocations (WW, 2008). This translates to 747mm for the Komati River, and 638mm for the Lomati River (table 3.5). With a rainfall of 590mm in 2007/2008 (SASRI, 2008a) the farmers theoretically had access to a water quantity of 1228 to 1337mm. In 2004/2005, however, the situation was drastically different. Following a severe drought, water restrictions reached 40-60%. During these years the IBs were more lenient towards the emerging farmers seeing how they were struggling with their irrigation systems (LIB-1, 2008). In 2004/2005 and 2005/2006 the water restrictions were 60% for the commercial farmers and 40% for the emerging farmers as recommended by the IB to DWAF (WW, 2008). Adding to this the rainfall of 419mm in 2004/2005, farmers' actual access to water ranged from 759mm (commercial farmers on the Lomati River) to 1016mm (emerging farmers on the Komati River), far below the crop water requirement.

Season	Full Allocations (mm/y)		Restrictions (%)		River Water Availability (mm/y)			
	Komati	Lomati	CF	EF	CF Komati	CF Lomati	EF Komati	EF Lomati
2004/2005	995	850	60	40	398	340	597	510
2005/2006	995	850	60	40	398	340	597	510
2006/2007	995	850	0	0	995	850	995	850
2007/2008	995	850	25	25	747	638	747	638
2008/2009	995	850	25	25	747	638	747	638

Table 3.5: Water allocations, restrictions and availability from 2004-2009 (WW, 2008: SASRI, 2008a).

Both commercial and emerging farmers were thus unable to reach the crop water requirement in 2004/2005. Even so, farmers on the Komati did have an advantage of water quantity. To assess the effect of these higher water allocations on the values of ET_a and biomass, histograms were plotted comparing values of ET_a and biomass for farmers on both rivers. These histograms can be found in Annex III-C. Figures 3.15 and 3.16 show 20%, 50% and 80% values for ET_a and biomass for commercial and emerging farmers on both rivers.

EMERGING FARMERS

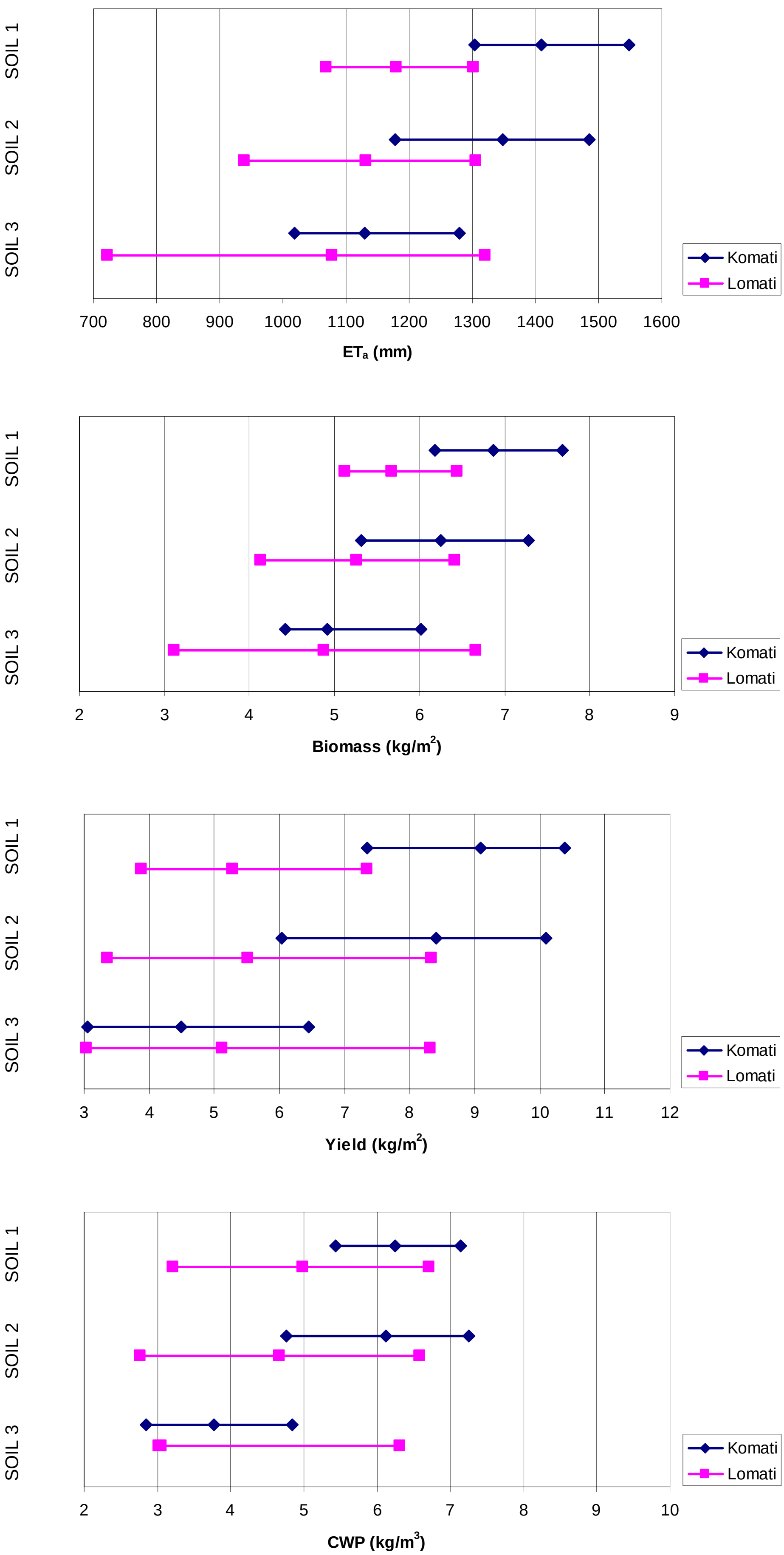


Figure 3.15: Graphs showing the range of values for ET_a, biomass, yield production and CWP for different water allocations of emerging farmers compared to the median.

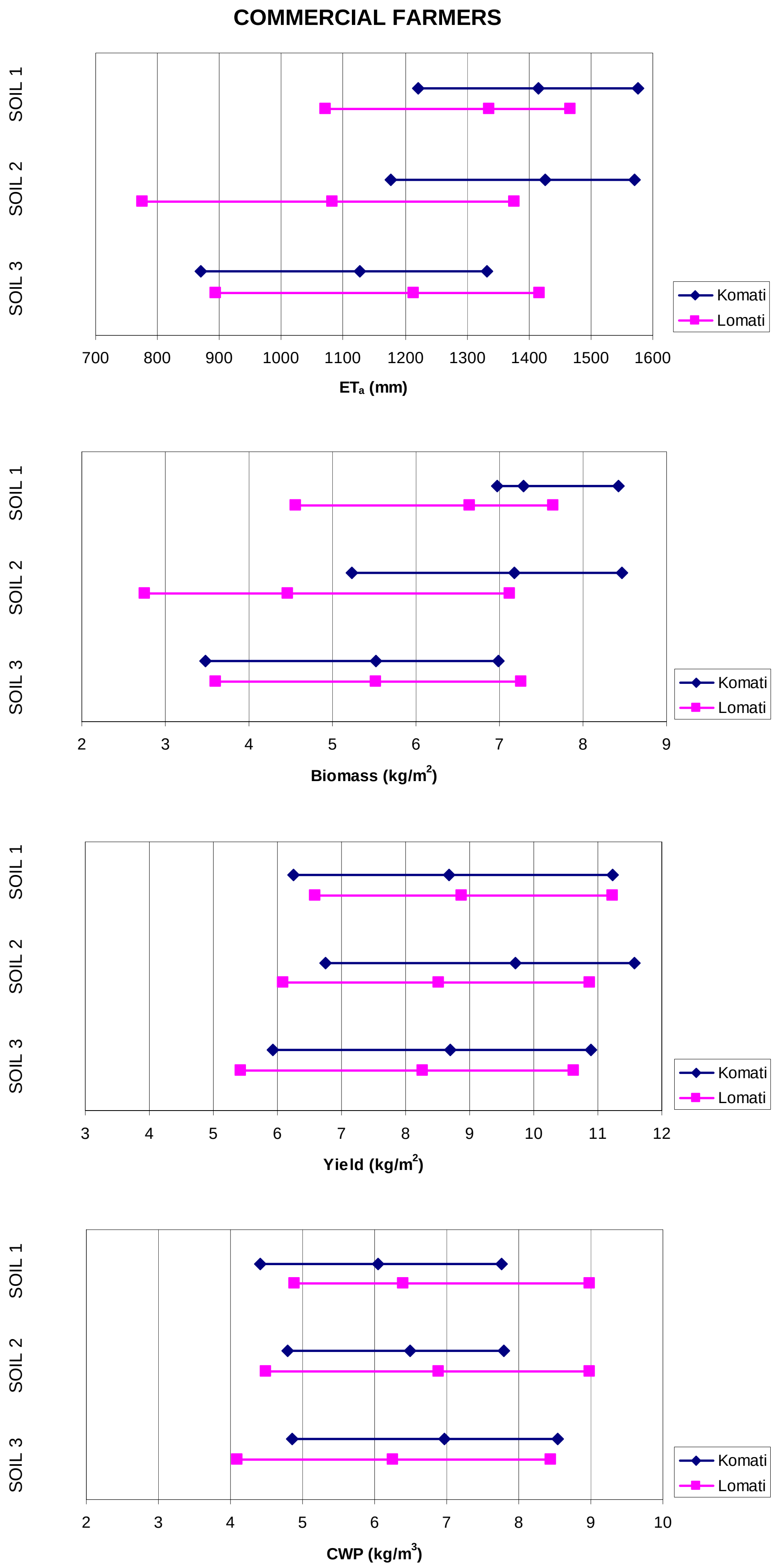


Figure 3.16: Graphs showing the range of values for ET_a, biomass, yield production and CWP of for different water allocations of commercial farmers compared to the median.

As mentioned before, soils with high clay content (soil class 1) are less sensitive to irrigation breakdowns than soils with low clay content (soil class 3). Frequency of irrigation should be higher when soils become more marginal. When an irrigation system breaks down, farmers on marginal soils will suffer first. The CWP is related to the availability of irrigation water and the type of irrigation system. It is expected that the range of values for ET_a and biomass will be larger for farmers on the more marginal soils, due to part of these farmers being able to increase production due to adequate irrigation systems.

For emerging farmers, values of ET_a and biomass decrease with soil type. This relationship was established earlier, and it seems that overall, farmers on the more marginal soils have trouble applying irrigation water timely and adequately compared to emerging farmers on the more fertile soils. This reflects the fact that 90% of the emerging farmers (all over the projects and soil classes) are still using sprinkler irrigation. Looking at the range of values of ET_a and biomass, the range does become larger when the soil becomes less fertile. The only exception concerns the farmers in soil class 3 who get their water from the Komati River. They do not have a particularly large range of values for ET_a and biomass. This indicates that these farmers are most probably all using similar irrigation systems, and that these farmers have failed to improve production by adjusting their way of applying water to their fields. Yield production of emerging farmers also seems to depend on soil type, indicating that farmers on the more marginal soils have trouble producing at optimal levels. Even so, differences in yield for farmers on the Lomati River are small, with farmers on soil class 2 having the highest median value. What is evident is that the farmers on soil class 3 who irrigate off the Komati River have very low values for yield production. Upon further exploration, it turns out that these specific farmers are located in Mzinti and Phiva. These two projects suffer from saline soils, which affect the yield production of certain plots. Moreover, as part of the 'seven projects' these two projects have had some problems with irrigation design. This issue will be discussed later in this chapter. CWP of emerging farmers also seems to depend on soil type. CWP is lower for the more marginal soils. These farmers are not only struggling with yield production, but it seems that their management practices are also lacking compared to the farmers on the more fertile soils.

Comparing emerging farmers on both rivers, it is clear that farmers on the Komati River have higher median values for ET_a and biomass than farmers on the Lomati River. This can also be seen in the histograms as there is a shift left along the x-axes for farmers on the Lomati River. Differences for soil class 3 are small, but the results indicate that the higher river allocation of the Komati River does benefit emerging farmers. Even with inadequate irrigation systems, a higher river allocation will help them to apply more water to their fields compared to farmers on the Lomati River. The higher river allocation of the Komati River also seems to benefit yield production and CWP of emerging farmers (except for the farmers in Mzinti and Phiva who have their own specific problems).

For commercial farmers soil class does not have such a significant effect on ET_a and biomass as it has for the emerging farmers. Differences between soil classes 1 and 2 are very small, except for the Lomati River. These farmers (soil class 2) have the lowest median values for ET_a and biomass of all commercial farmers. Their range of these values is very high as more individual farmers have low values for ET_a and biomass and are failing in supplying water to their fields adequately. Even so, their relatively high median yields and CWP indicate that there are also many individual successful farmers in this area. Along the Komati River farmers on the marginal soils (class 3) seem to have the most trouble applying irrigation water timely and adequately. Yield production does not seem to depend on soil type much, as farmers in soil class 2 who irrigate off the Komati River are producing the highest median yields, and farmers irrigating off the Lomati River all have very similar values for yield production. Looking at CWP, values are lowest for farmers in soil class 1 and highest for farmers in soil class 3. This was expected, as farmers in soil class 1 have the highest values for ET_a. However, this trend doesn't continue to farmers on the Lomati River, as CWP is lowers for farmers in soil class 3. Soil class thus doesn't have the same effect on yield production and CWP as it has for the emerging farmers.

Looking at the effect of water allocations, soil class 3 will be disregarded. This is because farmers in this area are located close to the confluence of the Lomati and Komati Rivers. As it was difficult to distinguish the exact water source of the farmers in this area, these results may be unreliable. The histograms and median values show that, similar to the emerging farmers, a larger water allocation does seem to have a positive effect on values for ET_a and biomass of commercial farmers, indicating that farmers on the Komati River are able to transfer more water to their lands due to these larger water allocations. A higher water allocation seems to have an effect on yield production for farmers in soil class 2, but not for farmers in soil class 1. The relative water stress for farmers on the Lomati River is being translated in higher values of CWP for these farmers. Again, the effect of water allocations on yield production and CWP is different from the emerging farmers.

Commercial farmers have relatively high values of yield production compared to the emerging farmers. Commercial farmers on the Lomati River are able to achieve higher yields than the emerging farmers on the Lomati River. Also, commercial farmers with marginal soils (class 3) have much higher yields than emerging farmers on the same soils. Knowing that emerging farmers had access to larger water allocations, it is likely that these differences reflect differences in management. Differences in management are related to factors within the farming system such as the application of fertilizers or weed control.

Although water restrictions are currently (2008) the same for all farmers in the Lower Komati, and emerging farmers are known to have been favoured in the past, the main perception among emerging farmers, who look at the high yields of the commercial farmers, is still that commercial farmers have a better deal of water (EF, 2008). On the other hand, commercial farmers are sometimes jealous of the leniency of the IBs towards the emerging farmers. In some aspects, e.g. irrigation systems and water storage facilities, commercial farmers seem indeed better off, but some still complain that the emerging farmers don't get restricted the way they do and accuse the emerging farmers of taking more than their fair share (CF, 2008). They overlook the fact that most emerging farmers are struggling to make a living of 7ha, while most commercial farmers are doing well on hundreds of hectares. It is true that the emerging farmers on the Komati River do not have water meters, and that it cannot be controlled if they really carry out their restrictions (CG-1, 2008; WW, 2008). These farmers have always refused to install water meters, feeling controlled by the whites, chasing the engineers away at gun-point (BT-2, 2008; PA, 2008; TSB-4, 2008). However, the water does get measured at Driekoppies Dam, before entering the area, and at the Tonga weir, after leaving the area, and these measurements indicate that the emerging farmers are not over-abstracting any water (TSB-4, 2008; WW, 2008). Coupling this with all the flaws and water losses in the irrigation systems of the emerging farmers (such as breaks, leaks, cable theft, low pressure, mechanical problems and general inefficiency) it actually seems like emerging farmers are using less than their allocated share. This is exactly why the IB advocates flow meters, and even had demonstrations and workshops for the farmers. However, the farmers refuse to install meters, and the IB has handed the issue over to DWAF, again accusing DWAF of refusing to take any action (LIB-1, 2008; WW, 2008).

An issue that many commercial farmers complain about, but that was not mentioned by any emerging farmers, is the perception that KOBWA uses a too low assurance for irrigation (CF, 2008). For high assurance (domestic uses) KOBWA supplies 100%. The irrigation demands are 85% low assurance (KOBWA-1, 2008), meaning that KOBWA tries to supply full irrigation allocations 17 years out of 20. As KOBWA tries to reach this assurance, and does not want the dam to fail in the future, it gives out strict restrictions in the current years to be able to reach the 85% in the future (KOBWA-1, 2008). However, farmers think the 85% is too high, and would rather have a lower assurance. They would rather receive a higher volume of water, while having it restricted more often. Now, even in good years, they feel that they cannot get access to all the available water (CF, 2008). The Inkomati Catchment Management Agency (ICMA) agrees with the farmers on this point (ICMA-1, 2008), but the system is difficult to change as all is based on internationally agreed rules between South Africa and Swaziland (KOBWA-1, 2008).

Water Allocation Reform

The issue of water allocations for commercial farmers has another interesting political aspect related to surplus allocations. DWAF and the ICMA, who are involved in the land and water reform processes, feel that the commercial farmers are using more than their fair share. This is related to the surplus allocations of commercial farmers on the Komati River. When the old water act was still in use water rights were based on riparian rights (Waalewijn *et al*., 2005) and the act stated that everyone could take their fair share of maximum 100l/s, basically “take as much as you want”, which only applied to people next to the river (ICMA-1, 2008). Blacks were not allowed to own land and thus did not have any water rights (ICMA-2, 2008). When the amount of farmers multiplied, IBs were formed to control the water better, and farmers were given their original water allocations of 995 and 850mm per year (LIB-1, 2008). As there seemed to be plenty of water in the river, DWAF allowed the commercial farmers to take more water during times of surplus conditions, i.e. floods and rains, and allowed them to double their original allocations during these times. Moreover, the commercial farmers were allowed to build dams for 50% of the surplus allocations (DWAF-1, 2008; ICMA-1, 2008). However, as there was no monitoring, DWAF and the ICMA are now accusing the commercial farmers of taking advantage of the offered generosity, and misusing their water rights. Many farmers built dams, and according to DWAF they had started to take their double allocations as their normal allocations, even in times of drought. With this extra water, and more efficient irrigation systems such as drip systems, farmers had extended their lands sometimes double or more the original size (DWAF-1, 2008; ICMA-1, 2008).

Over time, the extended farm sizes of the commercial farmers have come to form the basis of their current water allocations which are now seen as normal flow. DWAF and the ICMA argue that, effectively, commercial farmers have thus found a way to double their water allocations over time by incorporating their surplus allocations into their normal allocations. These are now recognized as an existing lawful use (DWAF-1, 2008; ICMA-1, 2008). Emerging farmers never had this benefit, and it may be argued that the emerging farmers only have access to half of what the commercial farmers are receiving. Commercial farmers may have larger lands, but the actual mm they are allowed to to take from the river is the same as for emerging farmers. However, having large storage dams, commercial farmers may apply more than their actual allocation in times of drought which may affect their ET_a, biomass, yield production and CWP.

Water allocation reform, which is related to land reform, states that 35% of the water rights need to be transferred from white to black hands before 2012 (DWAF-1, 2008). So far, 27% has been reallocated. The actual effect of land claims will also take care of the water allocation reform, and might lead to more than 35% being reallocated eventually (DWAF-1, 2008, ICMA-2, 2008). Due to these reforms, DWAF is now claiming that surplus flow is no longer applicable. DWAF argues that the commercial farmers have always had the benefit of water, and that this needs to change. It feels that these farmers have always been spoiled (DWAF-1, 2008). Now, with the New Water Act (NWA) farming has gotten a lower priority from the government, as it is not the most economical use of water. Instead of looking at hectares, the NWA aims to look at volumes (Brown & Woodhouse, 2004). Moreover, the NWA gives more attention to international obligations and the environment, which is now entitled to 30% of the available water, or 'The Reserve' (Schoch, 2007). All in all, DWAF and the ICMA feel that commercial farmers have always been treated as kings, but that it's time for things to change. New users must benefit from the same resource as well, and water needs to be used more efficiently (DWAF-2, 2008; ICMA-1, 2008). DWAF is planning on transferring some of the surplus irrigation rights to the emerging farmers after completion of the compulsory licensing process. This will give emerging farmers the option to extend their lands, but it also gives room for general farmland expansion, allowing more black people to become farmers. Currently, the DWAF and the ICMA are working on determining the economic effect of transferring water from commercial farmers to emerging farmers (DWAF-2, 2008; ICMA-1, 2008). This water allocation process will be spread out over a five year period, and the aim is for commercial farmers to either improve their efficiency, or to cut their land size. The five year time frame will give the emerging farmers time to focus on getting the needed infrastructure such as canals (DWAF-2, 2008).

Due to the water allocation process, many commercial farmers see the DWAF and ICMA as their enemies. They have a problem with DWAF and ICMA wanting to just 'take' their water instead of paying for it. They fear that the cane business will fall down when their water gets taken away as they claim that emerging farmers have no knowledge on how to farm. This will then affect the cane supply to TSB (CF, 2008). Commercial farmers believe that the emerging farmers are being favoured, which is indeed a key principle of the NWA. DWAF and ICMA feel that it is time to even up the score. Even so, emerging farmers are not happy either, as they still believe that the commercial farmers are being favoured by the IBs (EF, 2008). All in all people don't seem to cope with change well. It is a political game where everyone is suffering and accusing the other of having more water rights.

Another issue between commercial farmers and DWAF concerns the price they need to pay for water. DWAF levies for commercial farmers are ZAR483.08/ha/annum. This includes a consumptive charge of ZAR417.35, and a water resources management charge, including a water research levy, of ZAR65.73. The emerging farmers need to pay ZAR136.00 and ZAR65.73 respectively (ZAR201.73/ha/annum) (WW, 2008) but most of them don't pay as they can simply not afford it (EF, 2008). As the emerging farmers are not paying, many commercial farmers also refuse to pay DWAF. An overriding reason for this is that they think the people at DWAF are "crooks". They will not pay DWAF as they do not trust the money to come back to them to assist in their development (CF, 2008). DWAF cannot do much about this, as they are located in Pretoria, and the ICMA does not have the mandate to collect the funds (ICMA-1, 2008; LIB-1, 2008). However, farmers do pay the Irrigation Boards (IBs) as these function quite well on local level. They have the capacity to assist the farmers without needing the assistance of DWAF, and farmers have an interest their functioning. IB fees are ZAR101.70/ha/year for commercial farmers and ZAR41.57/ha/year for emerging farmers

(LIB-1, 2008). The chairman of the IB urges all farmers to pay their fees, as he believes it may become the basis for the government to decide from whom to take water away during the water allocation reform process (LIB-1, 2008).

3.3.2 Water Control

It is clear that water quantity influences ET_a, biomass, yield production and CWP. However, it cannot fully explain this diversity, as there is still a large spread of these values among the farmers in the Lower Komati. Therefore it is important to look at the way this water is controlled. Water control, timing and precision are essential, and are related to irrigation systems and irrigation efficiency. The manipulation of water on the farm, and the management skills of the farmers are important as water needs to gets to the crop effectively. To explain the diversity in ET_a, biomass, yield and CWP among farmers further, reasons should be sought in the socio-economic arena of water control, i.e. the way the farmers handle their irrigation systems. This paragraph will explore reasons for differences in irrigation efficiency among farmers and the way these affect the water quantity and the ET_a, biomass, yield and CWP.

3.3.2.1 Irrigation

In the Lower Komati, irrigation was designed to be supplementary for a period of four to six months during the summer (PA, 2008; TSB-4, 2008; WW, 2008). The 1200 to 1500mm per year that is ideally needed for sugarcane production should thus come from both rain and irrigation. It is generally perceived that the amount of water in the Lower Komati is not sufficient for maximum sugarcane production (BT-2, 2008; ICMA-1, 2008; PA, 2008; TSB-3, 2008). Farms were not designed for a 100% water allocation (DB, 2008; LIB-2, 2008), and with the new licensing system future allocations will be even smaller (DWAF-1, 2008). However, with good irrigation and good management, farmers should be able to achieve a yield production of 120ton/ha cane for all but 1000ha of the soils in the area. The other 10% of the soils has a potential of 90ton/ha (BT-2, 2008; PA, 2008). Although water quantity is not enough for maximum sugarcane production, many stakeholders argue that the farmers in the Lower Komati all have sufficient water allocations to make a living, and that water is not the limiting factor for yield production (BT-2, 2008; ICMA-1, 2008; PA, 2008; TSB-3, 2008).

Irrigation Type

As mentioned before, soil class determines the frequency of irrigation needed for optimal crop production. Class 3 soils (marginal, low retention capacity) are more sensitive to irrigation frequency than class 1 soils (fertile, high retention capacity). Marginal soils are more sensitive to irrigation break-downs. Irrigation type is thus an important factor influencing values of ET_a, biomass, yield production and CWP among farmers. Irrigation type is in turn related to the irrigation design. Engineers designed most smallholder projects for dragline sprinklers. Walda was designed for floppy sprinklers (DB, 2008) and farmers in Mbongozi and Boschfontein I use pivot irrigation. Over the years farmers have had the opportunity to change their irrigation system. In general, emerging farmers seem to favour drip irrigation over sprinklers as it is more water efficient, and can irrigate the whole plot in a smaller amount of time. It is also less labour intensive than draglines, and allows for fertigation. Sprinklers are more affected by theft as they consist of copper parts and farmers feel that water gets wasted when it’s windy outside (EF, 2008). However, due to the relatively high costs of drip, the choice of irrigation type depends on the farmers’ financial situation more than anything and very few emerging farmers have implemented drip irrigation so far. Besides being capital intensive, drip requires good management and needs constant monitoring.

Among the commercial farmers, a higher percentage is using drip and pivot irrigation compared to the emerging farmers, and all three systems are well represented among them (TSB, 2005). As pivot and drip systems are costly, this reflects the differences in their financial situation compared to the emerging farmers. An advantage that commercial farmers have over emerging farmers is the use of large reservoirs which they use to settle the water before it goes into the drip lines (CF, 2008). Emerging farmers need to monitor their drip lines more closely against blocking. Pivot irrigation is popular among commercial farmers, but can be a problem in times of severe water restrictions. When using sprinklers or drip, farmers can decide to irrigate fewer hours, and then turn off the drip system or move the sprinklers. With pivot this is not possible, as it is difficult to speed up the rotation of a pivot system (CF, 2008, TSB-4, 2008).

To assess the effect of irrigation systems of emerging farmers on values for ET_a, biomass, yield production and CWP, histograms were plotted once again (see Annex III-D). Only three emerging farmers were using the drip system back in 2004/2005 (TSB, 2005). Two farmers were located in Shinyokana (soil class 2). Their ET_a and biomass values were 898 and 910mm and 4.0 and 3.8kg/m^2 respectively. Both of them did not harvest any sugarcane in 2004/2005 making their yield production and CWP zero. Another farmer in Buffelspruit (soil class 1) also used drip irrigation and yielded 5.0kg/m^2 sugarcane. His ET_a was 1224mm, his biomass 5.7kg/m^2 and his CWP 4.1kg/m^3. Unfortunately, the lack of farmers using drip makes it difficult to compare the effects of drip to the effects of sprinklers and pivots on ET_a, biomass, yield production and CWP. Therefore, the effects of drip on ET_a, biomass, yield production and CWP for the 2004/2005 season will not be assessed.

In 2004/2005 most emerging farmers were using dragline sprinklers (90%). 6% of farmers used floppy sprinklers and the rest irrigated using center pivots. Floppy irrigation was limited to soil class 2 (Walda) and pivot irrigation to soil class 3 (Mbongozi and Boschfontein I). Figure 3.17 gives an overview of 20% and 80% values of ET_a, biomass, yield production and CWP of different irrigation systems of emerging farmers compared to the median. It is once again clear that soil type influences ET_a, biomass, yield production and CWP of emerging farmers. Focusing on dragline irrigation, median values are lower for soil class 3 and the histograms show a downward shift along the x-axes. Farmers on soil class 3 would be better off with a system that allows for irrigation water to be applied more frequently, e.g. drip. These results also indicate that, overall, farmers on the marginal soils have trouble applying correct management to improve their yield production.

Comparing drag line and floppy sprinklers in soil class 2, ET_a and biomass values are very close together. The range of values is larger for floppy sprinklers. This indicates that Walda houses some good managers who are able to adequately match the frequency of irrigation to the soil type. Floppy irrigation has a special design that allows farmers to irrigate frequently with minimum labour involved. Simply opening and closing a valve allows for very accurate irrigation. However, not all farmers know how to work this system and are unable to produce at optimal levels. This issue of irrigation design will be discussed in the next paragraph. Values for yield production and CWP are also similar for drag line sprinkler and floppy sprinklers. This is not surprising, as both irrigation types are very similar. For floppy sprinklers more individual farmers have higher values for yield production and CWP, than for

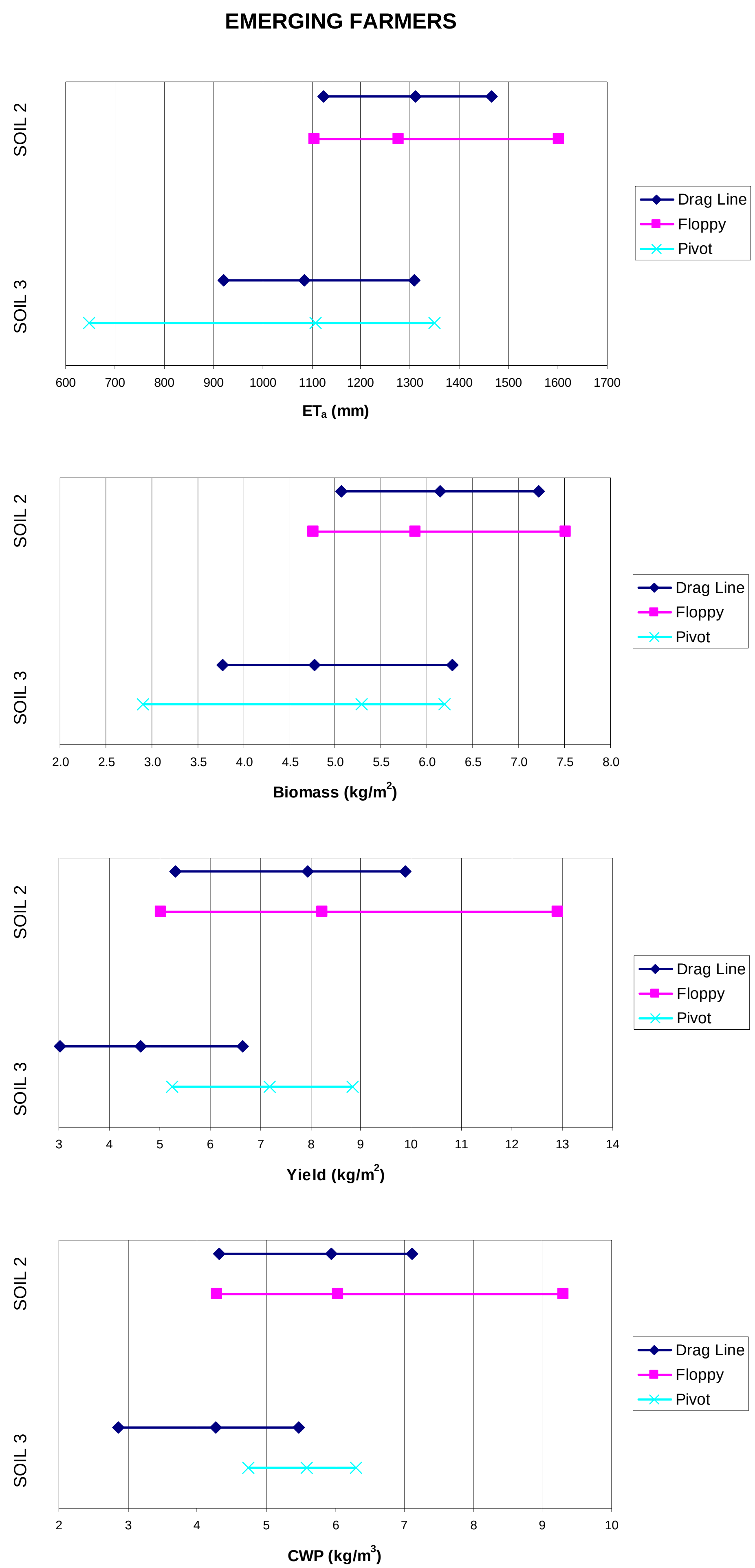


Figure 3.17: Graphs showing the range of values for ET_a, biomass, yield production and CWP of for different irrigation types of emerging farmers compared to the median.

drag line sprinklers. This may be due to good management practices of some farmers in Walda e.g. application of fertilizers or weed control.

Comparing drag line sprinklers and pivots for soil class 3, values for ET_a are again close together. Median values for biomass are slightly higher for pivot irrigation. The range of values for pivot irrigation is much higher as more individual farmers have low values for ET_a and biomass. This may be due to break-downs of the pivot system or theft of electricity cables. Once a pivot comes to a standstill, it will affect all farmers (usually eight) sharing this pivot. As fixing a pivot or replacing the cables may sometimes take months due to financial constraints, these farmers will all have low values for ET_a and biomass. Median yield is higher for pivot irrigation than for drag line sprinklers. The larger drop size of pivots may be a reason for this difference, as less water is evaporated due to wind replacement, and more water is used for transpiration. CWP is also higher for pivot irrigation, which is expected as values for ET_a are similar with the ones for drag line sprinklers, but yield is higher.

Over the years drip has gained more popularity among emerging farmers, but dragline sprinklers are still most widely used (TSB, 2007). The effect of irrigation type on yield production will be further explored for the 2006/2007 season using TSB yield data. Unfortunately, data on ET_a and biomass is not available for this season. Table 3.8 shows average yields for soil classes 2 and 3. Thirteen farmers in soil class 2 and three farmers in soil class 3 are using drip irrigation (TSB, 2007).

MEAN VALUES - EMERGING FARMERS			
SOIL 2	**Drag Line**	**Floppy**	**Drip**
Yield (kg/m^2)	**6.5**	**7.3**	**9.8**
SOIL 3	**Drag Line**	**Center Pivot**	**Drip**
Yield (kg/m^2)	**4.0**	**6.3**	**15.5**

Table 3.6: Mean values of yield production for emerging farmers in soil class 2 and 3 using drag line, floppy, pivot and drip irrigation (2006/2007 season).

This time, yield for floppy sprinklers iss higher than yield for drag line sprinklers (soil class 2). As biomass should be similar for these two irrigation types, it is likely that the farmers in Walda have improved their management practices over the years. In soil class 3, yield for pivots is higher than yield for drag line sprinklers. The same relation was established for the 2004/2005 season. The high yield values for drip irrigation in both soil classes reflect the high irrigation efficiencies of this system (±95%). This means that almost all water applied to the plant is used for transpiration, and very little is lost to evaporation. It seems that farmers using drip irrigation have successfully adjusted their irrigation system to the soil type. Soil class 3 is very sensitive to irrigation, but by installing drip farmers are able to irrigate more precisely and more frequently (with smaller amounts) compared to sprinklers and pivots. It must be noted that sprinklers and pivots are more affected by theft than drip systems. The copper parts of the sprinkler systems (e.g. nozzles) and the electricity cables of the pivots get stolen regularly. This affects the workings of these irrigation systems, and their low average yields may be partly due to the stealing of irrigation equipment.

It must be noted that 26% of all emerging farmers (2007) are not producing anything at all (TSB, 2007). This includes a third of the farmers using drip irrigation. Differences in yield production are thus not only related to irrigation type, but also to management. Drip irrigation is more water efficient in general, but good management and maintenance of the drip lines are essential for it to function well. An example concerns one lady farmer who is using the drip system but is suffering from zero yields as she does not know how to look after it. Her drip lines are blocked and her yields have deteriorated fast. Other fields with zero production concern plots that have been abandoned by retired farmers or by people with other jobs. When looking at the individual yields of farmers in soil class 2, 6% of farmers using drag line sprinklers are yielding over 100 ton/ha (10kg/m^2). This also reflects a difference in management as they are far above the season average of 64ton/ha. This means that even though sprinklers have a lower irrigation efficiency compared to drip, this does not necessarily have to affect the yield when good management is in place. It must be stressed that some commercial farmers also have zero yields for sugarcane. However, these farmers still produce yields from their other crops, while emerging farmers only grow sugar.

To assess the effect of irrigation system on values of ET_a, biomass, yield production and CWP of commercial farmers, more histograms were plotted (Annex III-D). Figure 3.18 gives an overview of 20% and 80% values of ET_a, biomass, yield production and CWP of different irrigation systems of commercial farmers compared to the median. It is clear that median values of ET_a and biomass are close together for all the irrigation systems. An exception concerns the values for pivot irrigation in soil classes 2 and 3. These values are very high. As there are only few farmers irrigating with pivots in these soil classes, it seems that these specific farmers have found ways to adjust the irrigation frequency of their pivots to the soil type accordingly. Focusing on yield production, these values are highest for the drip system and lowest for the pivot system for soil classes 1 and 2. Higher yield values for sugarcane irrigated by a drip system indicate that the fraction of transpiration by sugarcane is higher than that for pivot or drag line sprinklers. Attributing to this is the fact that pivots and sprinklers are overhead systems, meaning that a certain amount of water will drop onto the leaves and evaporate before it gets to the plant, reducing the amount of transpiration under these systems. Another advantage of the drip system is that fertilizers can be added to the crop more effectively using fertigation (many commercial farmers do make use of fertigation, something that is not common among emerging farmers). Fertigation results in a smaller loss of applied fertilizers than when adding fertilizers by spraying, and it may contribute to the higher yield production. This explains the good performance of drips for soil classes 1 and 2, but for soil class 3 drag line sprinklers are performing better than drips. A reason for this can be that the farmers using drip have failed to manage it accordingly e.g. the lines may be blocked. Or the farmers using drag lines have managed to adjust the irrigation frequency of their systems to the marginal soils better. The good yields under drag line irrigation may also be related to management practices of these farmers, such as the application of fertilizers. The bad performance of pivots may be related to the frequency of irrigation. Draglines and drips can be positioned where the farmers want, and be turned off and on easily. Farmers are able to favour certain parts of their plots in times of water scarcity. A pivot, however, needs to rotate at a certain speed, and does not allow for the frequency of irrigation to be regulated much. The frequency of irrigation may thus not be suited accordingly to the type of soil. The low yields under pivot irrigation may also be related to the management practices of these specific farmers.

Even so, comparing biomass and yield production, there seem to be some discrepancies. For soil class 1, biomass values of all three systems are very close together. Yield values, however, differ significantly. For the pivot system, the median value for biomass is higher compared to the other irrigation systems, but the yield production is lower. Similarly, in soil class 3, biomass of the drip system is higher compared to drag lines while the yield production is lower. This cannot be explained at this point, and more in-depth research is recommended.

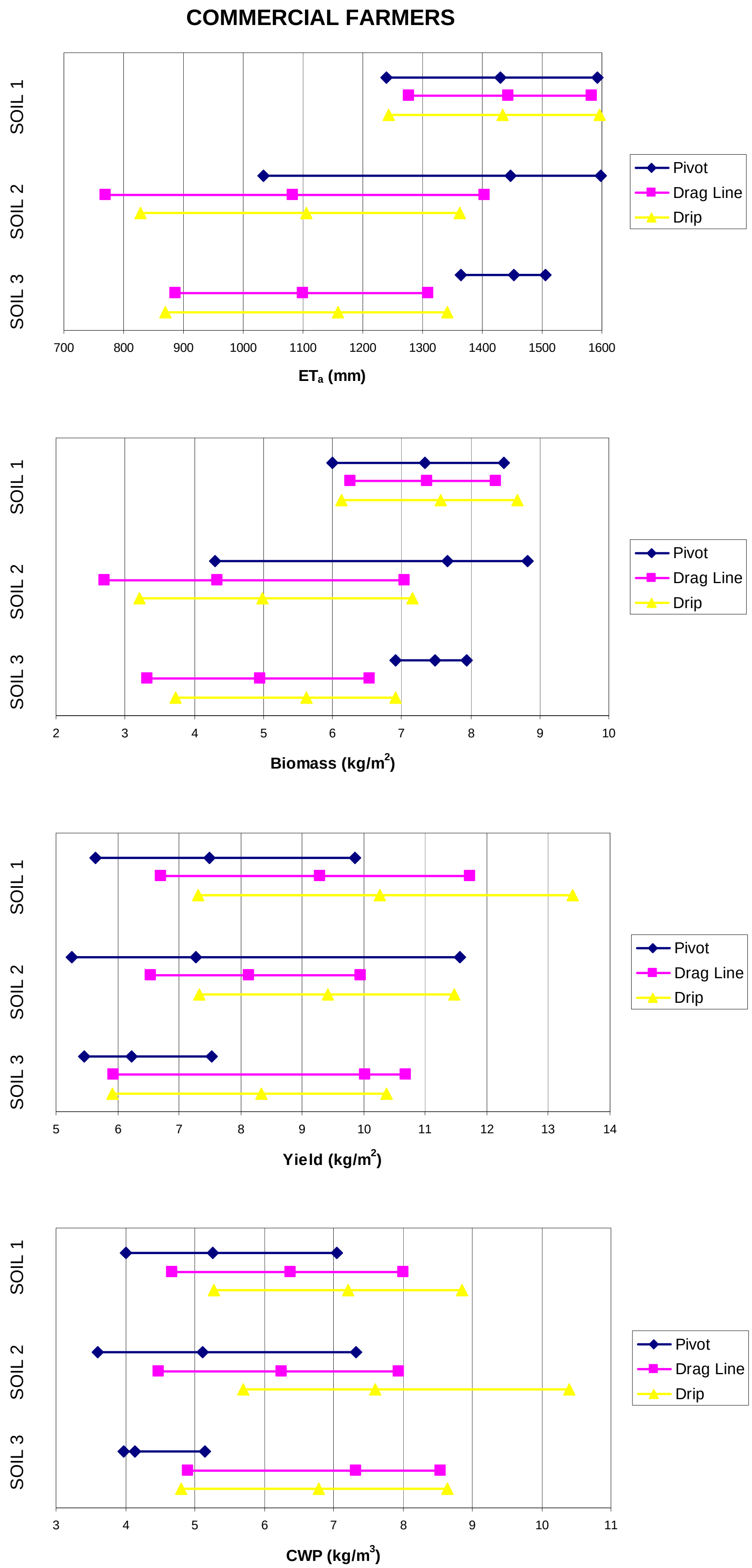


Figure 3.18: Graphs showing the range of values for ET_a, biomass, yield production and CWP of for different irrigation types of commercial farmers compared to the median.

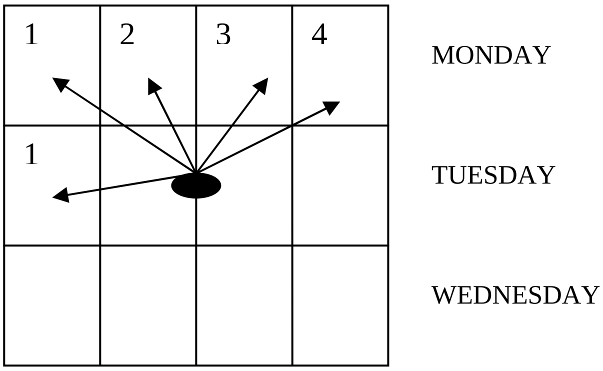
CWP follows the same pattern as the yield production. CWP is lowest for pivot irrigation and highest for drip in soil class 1. This is expected, looking at the different yields for these systems and their similar values for ET_a. A high value of ET_a for pivot in soil classes 2 and 3, and the low values for yield production, lead to the lowest values of CWP in these soil classes. CWP values for drag line and drip in soil classes 2 and 3 are as expected, based on their ET_a and yield production values.

It seems that values for ET_a and biomass of commercial farmers are less affected by soil type compared to the emerging farmers. This indicates that, in general, commercial farmers have found better ways to adjust their irrigation systems to the marginal soils. Soil class is thus less of a constraint for ET_a and biomass of commercial farmers than it is for emerging farmers. Yield production and CWP of commercial farmers however, seem to follow a similar pattern to that of emerging farmers, as these values are lowest for soil class 3, indicating that these farmers are struggling more than the farmers on the more fertile soils.

This paragraph has shown that the type of irrigation may influence ET_a, biomass, yield production and CWP of sugarcane farmers. However, there are differences between commercial and emerging farmers. On the most marginal soils (class 3) emerging farmers with drip systems are producing the highest yields, while commercial farmers with sprinklers perform better than commercial farmers with drips. Emerging farmers with pivots have higher average yields than emerging farmers with sprinklers. For commercial farmers this is the other way around. Soil type has a bigger impact on the yields of emerging farmers than on the yield of commercial farmers, indicating that commercial farmers are better at adjusting their irrigation frequencies to the soil type. Besides the irrigation system, other factors may also influence water quantity, and thus ET_a, biomass, yield production and CWP among farmers. These factors concern the design and management of the irrigation systems, and the effective conveyance of water to the fields.

Irrigation Design

When looking at the smallholder projects there seem to be some problems with design. The projects on the Eastside of the Komati River were developed by MBB, the projects on the Westside by Duplessis & Burger (DoA-1, 2008). Both companies, who were appointed by the Department of Agriculture (DoA), had a different approach in terms of design, and both sides currently suffer from problems. However, it seems that the projects designed by MBB are doing better than the rest when it comes to using the available water efficiently, as the designs by Duplessis & Burger are criticized most by several stakeholders (DoA-1, 2008; EF, 2008; ICMA-1, 2008; LIB-1, 2008; PA, 2008; SASRI-1, 2008; TSB-4, 2008). They argue that Duplessis & Burger relied solely on civil engineers, leading to flaws in their desktop designs. An example often mentioned is that Duplessis & Burger installed pivots in Mbongozi and only found out after installation that this project has huge boulders. This of course caused problems with the operation of the pivots. According to these stakeholders the soil investigations were not done properly, as these engineers were working with a ‘civil’ mindset, doing hydraulic calculations, and interpreting soil maps differently from agricultural engineers. MBB seemed to handle the designs differently. They had agricultural engineers involved in the design, and not only looked at soil reports, but also did practical tests. The designs by MBB are generally seen as more successful. An example is the floppy irrigation at Walda. Walda does not have particularly good soils, as they are prone to water logging. Floppy irrigation is seen as a great design by quite a few stakeholders as water gets applied in smaller amounts but more frequently. Walda has 10ha plots, which are divided into 12 blocks with a cluster valve in the middle. Simply opening and closing the valve allows for accurate scheduling and will take about 10 minutes. It is therefore much less labour intensive than dragline sprinklers. The design was based on a 3-day cycle, changing the cluster every 3 hours (figure 3.19).



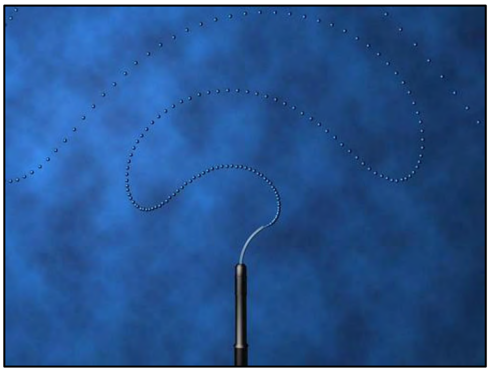


Figure 3.19: Schematic representation of the scheduling of a floppy system (left) and the floppy nozzle (right) (Floppy Sprinkler, 2009).

A main difference in design between MBB and Duplessis & Burger concerns water storage. The MBB projects have balancing dams which have the capacity of one day of irrigation. There is also a far off general storage dam near Spoons 7B: the Masibekela Dam. This dam is fed by the Komati River and pumps river water in times of rain. It acts as a back-up for the projects along the Komati River and it is managed by TSB and the IBs (TSB-4, 2008; WW, 2008). The Duplessis & Burger designs do not have any storage capacities and take water directly from the river. Farmers are divided over this issue. Many would like to have a dam, as it means that they will have a water buffer when there is no irrigation due to theft of electricity cables or break-downs. Other farmers argue that the electricity and maintenance costs for systems with balancing dams are too high as extra pumps are needed, and they are happy with taking water directly from the river (EF, 2008). The differences in design between MBB and Duplessis & Burger may help explain the differences in ET_a, biomass, yield production and CWP among farmers, as the designs of MBB suffer less from breakdowns due to design flaws, are generally perceived to be using water more effectively, and allow for a (small) water buffer. This relates to higher expected values for ET_a and biomass and yield production. CWP is a different matter, as the water stress in the projects by Duplessis & Burger may lead to a higher CWP. However, too much water stress will affect the crop production negatively. Another issue concerning the design of the projects is related to the ongoing drought. Over the years there have been several floods in the Lower Komati, and the flood of 1986/1987 started the initiative to build a pumping house above the 1/200 flood line (BT-2, 2008). Ntunda, Sibange and Spoons 8 were all designed to irrigate with a full weir. However, due to the drought, and the destruction of the weirs in 2000, these projects all have a pump house that is now high above the river level. As the weirs were never rebuilt these projects now suffer from suction problems, affecting water quantity supply to these projects.

The storage capacities of the emerging farmers can in no way be compared to the huge off-channel dams of the commercial farmers, who are still able to irrigate for weeks when their irrigation system comes to a stand still, thereby covering periods of droughts. These dams allow farmers to regulate their irrigation frequencies better compared to farmers who take water directly from the river. These dams were built by the farmers themselves, who obviously had the resources (e.g. knowledge and finances) to do so (CF, 2008). They have also had significant assistance from the government, as, during Apartheid, most of the government's investment in storage dams and other irrigation infrastructure such as canals were intended for the white (ICMA-1, 2008). Although not all commercial farmers have off-channel dams, most have a storage capacity of weeks which benefits them during droughts, break downs of pumps, and electricity problems. With these dams farmers are able to distribute their water more accurately over time, and the presence of water storage facilities may have a positive influence on ET_a, biomass and yield production. Due to the size of these storage dams it is expected that commercial farmers with dams have higher values for ET_a, biomass, and yield production than emerging farmers with dams. CWP may be higher among emerging farmers, as their sugar is more susceptible to water stress.

Besides storage dams, many commercial farmers have access to boreholes and are using groundwater to supplement their irrigation (CF, 2008). The emerging farmers do not have boreholes, as these didn't come with the designs, and they don't have the resources to dig them themselves (EF, 2008). The boreholes of the commercial farmers were considered private in the past, and were not controlled in the old Water Act. These farmers were free to dig, had access to extra water and many extended their lands. When the NWA was established in 1998, the old boreholes were recognized as a lawful existing use, and these farmers were allowed to carry on using what they were using before 1998 (DWAF-1, 2008; ICMA-1, 2008). These farmers are thus allowed to use borehole water on top of their river allocations, which influences their values for ET_a, biomass, yield production and CWP. However, in 2004/2005 many boreholes were dry due to the drought, and the influence of borehole water is assumed to be limited during this season. Since 1998 farmers need authorization to dig new boreholes. These new boreholes cannot be used as an 'extra' water source anymore, as current water allocations consider the river and the boreholes to be one resource (DWAF-1, 2008; ICMA-1, 2008). It is questionable whether this borehole water is really not being used as an extra water source, as DWAF and ICMA do not know much about the amounts of groundwater being abstracted. There are no figures on actual groundwater use, but the ICMA is planning a groundwater use assessment starting in 2009 (ICMA-1, 2008).

One problem with farmers using boreholes is that they are outside the jurisdiction of the IB. The IB admits that these farmers cannot be controlled and that they are not sure how much water these farmers are using (ICMA-1, 2008; LIB-1, 2008). Only when a WUA is formed, will the IB be able to control these farmers. Unfortunately, the WUA transformation process is not moving forward as there are struggles between DWAF and the IB (DWAF-2, 2008; KRIB-2, 2008; LIB-1, 2008). It must be noted that some commercial farmers rely on boreholes only and do not have a river allocation, e.g. when a farmer bought a cattle farm without water rights and then started growing sugar (CF, 2008). These farmers are really suffering at the moment because of the drought and the drop in groundwater level. They suffer from a limited water quantity affecting their ET_a, biomass and yield production negatively.

'The Seven Projects'

A different case all together concerns 'the seven projects'. These projects were developed by Duplessis & Burger in 2001 after MBB pulled out (DoA-1, 2008). The soils of these projects are particularly marginal compared to the other projects, consisting largely of sand and rocks. The state of the soil corresponds to low water holding capacities, and lowers the amount of water effectively used for ET_a and biomass production. It will also negatively affect yield production although the CWP might increase as long as the water stress is not too severe. The engineers cannot be blamed entirely for development on these soils as the tribal authorities were responsible for allocation of sugarcane lands. The better lands had already been taken for other purposes such as housing and grazing, and the whole development of the seven projects was troubled by a shortage of land (DoA-3, 2008; TA, 2008; TSB-3, 2008). The DoA could therefore not use the best soils for development, and was forced into certain areas (DoA-2, 2008; DB, 2008).

The development of the seven projects was plagued by internal struggles within the government. In 1994, people at the DoA tried to stop development in Phiva after looking at soil maps of the area, not believing in the management capacities of the emerging farmers (DoA-1, 2008). The soil had already been evaluated by then, and the soil at Phiva was assessed as bad soil needing high management. However, officials at the Department of Agriculture and Land Affairs (DALA) pushed the project through, arguing that the government had already given a grant for development, that the land was already promised to the farmers, and that Ka Ngwane had already allocated the plots. It was a political game, and they had to go through with it. The money was there, the land was there, and development was continued (DALA-2, 2008).

Besides the problem of the bad soils, Duplessis & Burger are accused of making the designs of the seven projects non user-friendly, designing them with a too high application rate. Engineers (DoA-1, 2008; PA, 2008; TSB-4, 2008) are of the opinion that floppy or drip irrigation would have been a solution for the bad soils of Phiva, and disagree with the design of dragline sprinklers that are to be moved every three hours. Moving dragline sprinklers is a time-consuming job as people have to walk through the sugarcane which can be up to 3m high. The general norm for design was 3 sprinklers/ha (DoA-1, 2008; PA, 2008; TSB-4, 2008). Duplessis & Burger went with a lower amount of sprinklers, and a higher application rate, meaning that the sprinklers had to be moved more often (DB, 2008). The MBB designs are considered better in this aspect. They used more than 3 sprinklers per ha, which gave the sprinklers a longer standing time (DoA-1, 2008; PA, 2008; TSB-4, 2008). According to Duplessis & Burger the problem is not in the design of the projects, but in the farmers themselves and the way they maintain and manage their plots. Duplessis & Burger accuse the farmers of modifying their systems (DB, 2008). This can be seen all over the projects, not just in the seven projects. Even in Walda with its floppy irrigation design farmers wanting more water are taking nozzles of the sprinklers and using cut draglines as a hose. With farmers' adjustments the flow through the draglines and sprinklers has increased, leading to lower water pressure in many projects. Due to the lower water pressure the water quantity arriving at the plant has diminished. This in turn leads to lower values for ET_a, biomass and yield production. CWP on the other hand may be positively affected by the lower pressure. Duplessis & Burger does not see anything technically wrong with the designs. They do acknowledge that there might have been some flaws, the biggest one being that the link between operations and technology was too easy to bypass (DB, 2008). And as design criteria were never given (DB, 2008; DoA, 2008) the question remains if Duplessis & Burger are really the ones to be blamed. In the end issues about designs seem to be mainly differences of opinion.

Theft

A major problem which affects the irrigation systems, and with that the ET_a, biomass, yield production and CWP of all farmers in the Lower Komati, is the problem of theft. Besides the drought, both commercial and emerging farmers indicate that theft is their number one problem affecting their water quantity (EF, 2008; CF, 2008). It seems almost unstoppable, and affects all farmers in the area. The selling of scrap metal is good business in South Africa, leading to theft of nozzles, electricity cables, valves, and even transformers. Other items such as draglines and fertilizers get stolen to be re-sold or used in the households. Emerging farmers in particular get very emotional about the theft, and try to catch the thieves themselves, handing them over to the police. However, they often get disappointed by the police, as the thieves usually get released due to lack of evidence as farmers do not have proof of ownership. Farmers often complain about unhelpful and inexperienced policemen, and have lost faith in the South African legal system (EF, 2008).

The problem of theft is that the irrigation system comes to a stand-still. Without electricity cables the pumps don't work. Eskom, the electricity company, shares the responsibility of replacing electricity cables, but takes its time to replace them (EF, 2008). The farmers themselves are responsible for the electricity cables located on their lands. However, it may take weeks for emerging farmers to organize and for the cables to be replaced, only to be stolen again later. On top of this, the continuously needed replacements of stolen nozzles, sprinklers and draglines obviously affect their financial situation. As farmers don't budget for theft, all expenses related to theft are an extra strain. The farmers in Mbongozi (with their pivot system) are especially affected by the stealing of electricity cables, and are struggling to replace them. Adding to this is the problem that eight farmers share one pivot. Without electricity, farmers sometimes have to wait weeks or even months for the pivot to reach their plot. This is again related to the problems of farmers having to work together to solve their problems. The theft also affects the irrigation scheduling of the farmers. Due to financial constraints and problems with organizing, the pump or the pipelines often do not get fixed immediately. Once they are fixed, farmers want to catch up, and they apply too much water to their crop. This leads to over-irrigation and water wasting (TSB-4, 2008). Many farmers cannot afford a security system, although the question is whether an alarm will be useful as most farmers do not live close to their plots. The people do not guard their pumps and their irrigation systems at night, as they are afraid of the thieves who carry guns and will kill. The farmers have now resorted to putting their cables into concrete, and welding their pump machines shut (EF, 2008). Many farmers replace their copper nozzles with plastic ones, but these are not as durable as they get damaged easily by sunlight and by falling to the ground.

Commercial farmers usually keep replacing their stolen goods, but get frustrated by constantly having to buy new equipment. One farmer complained about spending ZAR20.000 per week on replacements (CF, 2008). Security systems are not much in use as the huge land sizes make security systems costly. Moreover, once the alarm sounds, the lands are too big to immediately catch the thieves. Many farmers replace their copper with plastic or aluminium. Some farmers have housed their labourers near the pump stations to scare of thieves. Others have started with imprinting their names on every 50cm of cable, and on every loose piece of equipment. One farmer has painted his entire fence a bright yellow and took pictures of it. Measures like these will allow them to have proof of ownership when the thieves get caught.

3.4 Conclusion

This chapter started with giving an overview of the distribution of ET_a, biomass, yield production and CWP of sugarcane plots in the Lower Komati. In order to explain the reasons for this diversity among commercial and emerging farmers, the influence of climate and soil on these four parameters was assessed. Climate seemed to have some influence on values for ET_a, biomass, yield production and CWP, but differences between climate zone 3 and 4 were small. The Lower Komati sub-catchment may thus be too small to have distinctively different climatic zones. Soil fertility proved to have a larger impact on values for ET_a and biomass as these values generally decrease as the soil becomes more marginal. This effect was especially clear among the emerging farmers. This indicates that commercial farmers have in general been more successful at adjusting their irrigation frequency (and systems) to the marginal soil types. Values of yield production among emerging farmers also decrease as the soil becomes more marginal, while soil fertility does not have much influence on the yield production of commercial farmers. This again indicates that commercial farmers have generally been more successful at adjusting their management practices to the more marginal soil types.

Besides exploring crop-physiological factors influencing ET_a, biomass, yield production and CWP, water quantity was explored in a socio-economic way to explain the spread in values further. Water allocations and irrigation types proved to have an effect on ET_a, biomass, yield production and CWP among farmers, especially among emerging farmers. Emerging farmers on the Komati River seemed to translate their higher river allocations to higher values for ET_a, biomass and yield production. This indicates that even with inadequate irrigation systems they are still able to transfer more water to their fields due to these higher allocations. Larger water allocations of the Komati River also had an influence on values of ET_a and biomass for commercial farmers, but less for yield production. This indicates that even with water stress, commercial farmers are still able to produce relatively high yields. Irrigation type may also influence ET_a, biomass, yield production and CWP of farmers, but the actual effect remains unclear as there was no clear pattern to be found and the effects differed between commercial and emerging farmers.

Other socio-economic factors related to water quantity, such as design and theft were discussed qualitatively as these factors are also likely to influence the diversity in ET_a, biomass, yield production and CWP. Even so, this diversity has still not fully been explained. Plots with similar characteristics (e.g. same type of farmer, same soil, same water allocation, same irrigation type and same design) still have different production values. The final explanations for this diversity need to be sought in the farming systems of the farmers. The farming systems include the socio-economic aspect of soil fertility (fertilizers), as well as aspects related to management, commitment and finances. The next chapter will look into the different farming systems of the area, and will give final explanations for the diversity in ET_a, biomass, yield production and CWP among commercial and emerging farmers in the Lower Komati.

CHAPTER 4: EXPLORING THE DIFFERENT FARMING SYSTEMS IN THE LOWER KOMATI

The previous chapter explored the influence of climate and clay content of the soil on actual evapotranspiration (ET_a), biomass, yield production and crop water productivity (CWP) of sugarcane farmers in the Lower Komati. It also discussed socio-economic factors of water quantity. The variation in ET_a, biomass, yield production and CWP has now partly been explained. This chapter will explore the final explanations for this diversity as related to the farming systems of the farmers. To do so, farming typologies will be set up of sugarcane plots with the same physical characteristics. Within each farming typology, the presence of both sub-optimal and optimal farmers will be explored. The focus will be on factors that can be managed better within the different farming typologies, such as water, fertility, and crop, in order to show possibilities for sub-optimal farmers to become optimal farmers. As the previous chapter discussed socio-economic aspects of water quantity, this chapter will, among others, focus on socio-economic aspects of soil fertility (fertilizers).

4.1 COMMERCIAL FARMING TYPOLOGIES

Within the commercial farming system, different farming typologies can be established. Chapter 3 discussed physical characteristics of sugarcane plots of commercial farmers which form the basis for these typologies. Different typologies will set different standards for farmers to improve their water, fertilizer and crop management. As can be concluded from chapter 3, the influence of soil class on the diversity in ET_a, biomass, yield production and CWP is larger than the influence of climate. Values for ET_a and biomass decrease when the soil becomes more marginal. It was also established that there is a larger range of these values for farmers on the more marginal soils, meaning that part of the farmers on marginal soils have found ways to adjust their irrigation frequency to the soil type, while others haven’t. Yield production and CWP also decrease with soil type, indicating that farmers on marginal soils are generally struggling more with their management inputs. The influence of crop variety on yield production was difficult to establish, as yield production may also be affected by other factors such as management (e.g. the application of fertilizers or weed control) or theft of irrigation equipment. Water allocations proved to have an influence on ET_a and biomass of commercial farmers, with an advantage for farmers on the Komati River. They did not have much influence on yield production however. Irrigation type also had some effect on values of ET_a, biomass, yield production and CWP of commercial farmers. Overall, pivot irrigation turned out to be the worst performing irrigation system for yield production, while it had the highest values for ET_a and biomass. Differences between drips and sprinklers were small, especially on the more marginal soils. Chapter 3 set the base for the different farming typologies of commercial farmers, which can be classified according to soil class, water allocation and irrigation type. One farmer can be part of more than one typology as a farmer may use more than one irrigation type or owns more than one farm in different areas. Figures 4.1 and 4.2 give an overview of yield production values of all commercial farmers on the Komati and Lomati Rivers respectively in which these different farming typologies can be identified. Maps of ET_a, yield production and CWP can be found in Annex IV.

OVERVIEW OF FARMING TYPOLOGIES OF COMMERCIAL FARMERS ON THE KOMATI RIVER

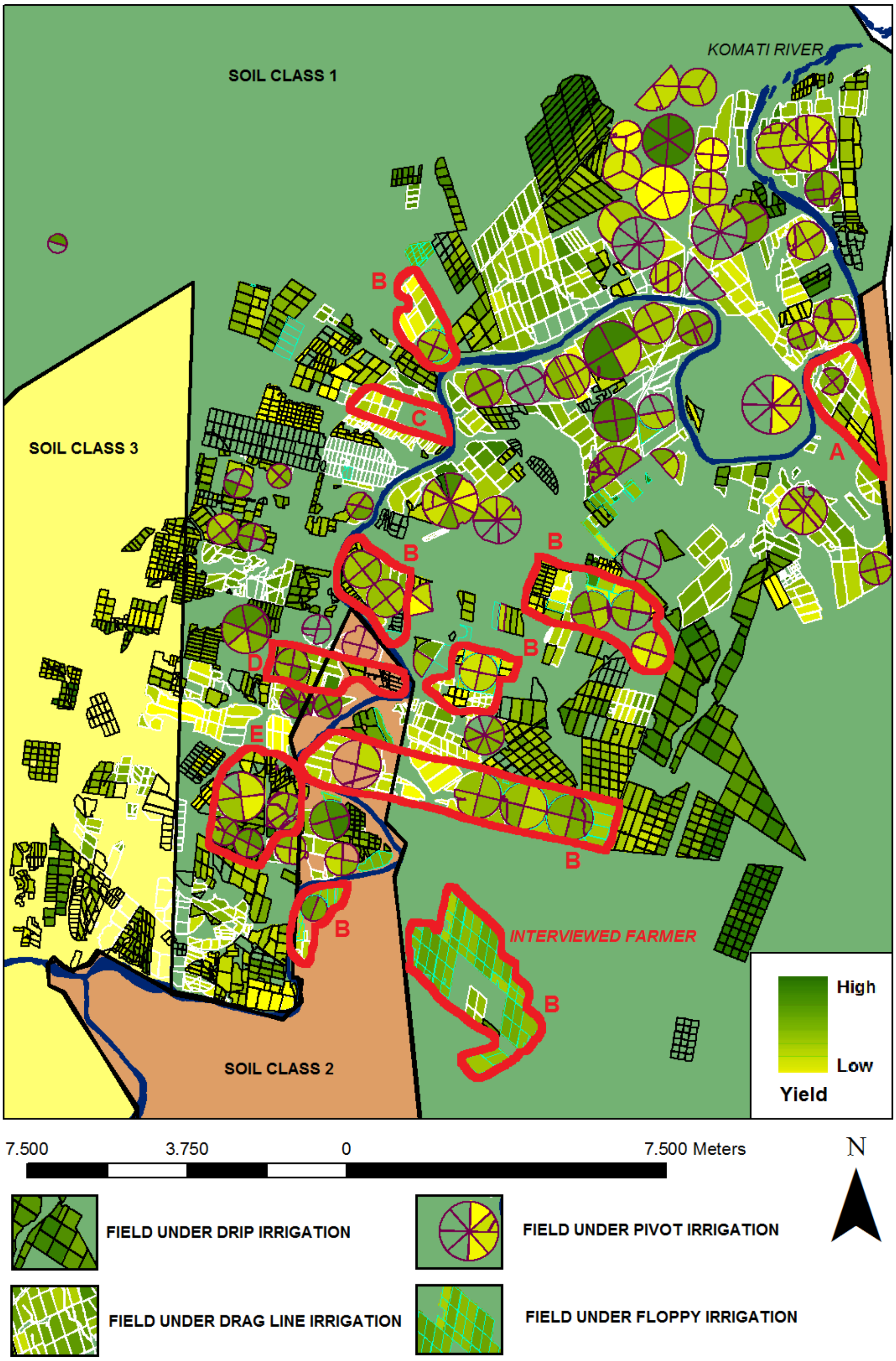


Figure 4.1: Overview of yield production for different farming typologies of commercial farmers on the Komati River. N.B. It was difficult to establish the exact water source of farmers in soil class 3. These farming typologies may be overlapping.

OVERVIEW OF FARMING TYPOLOGIES OF COMMERCIAL FARMERS ON THE LOMATI RIVER

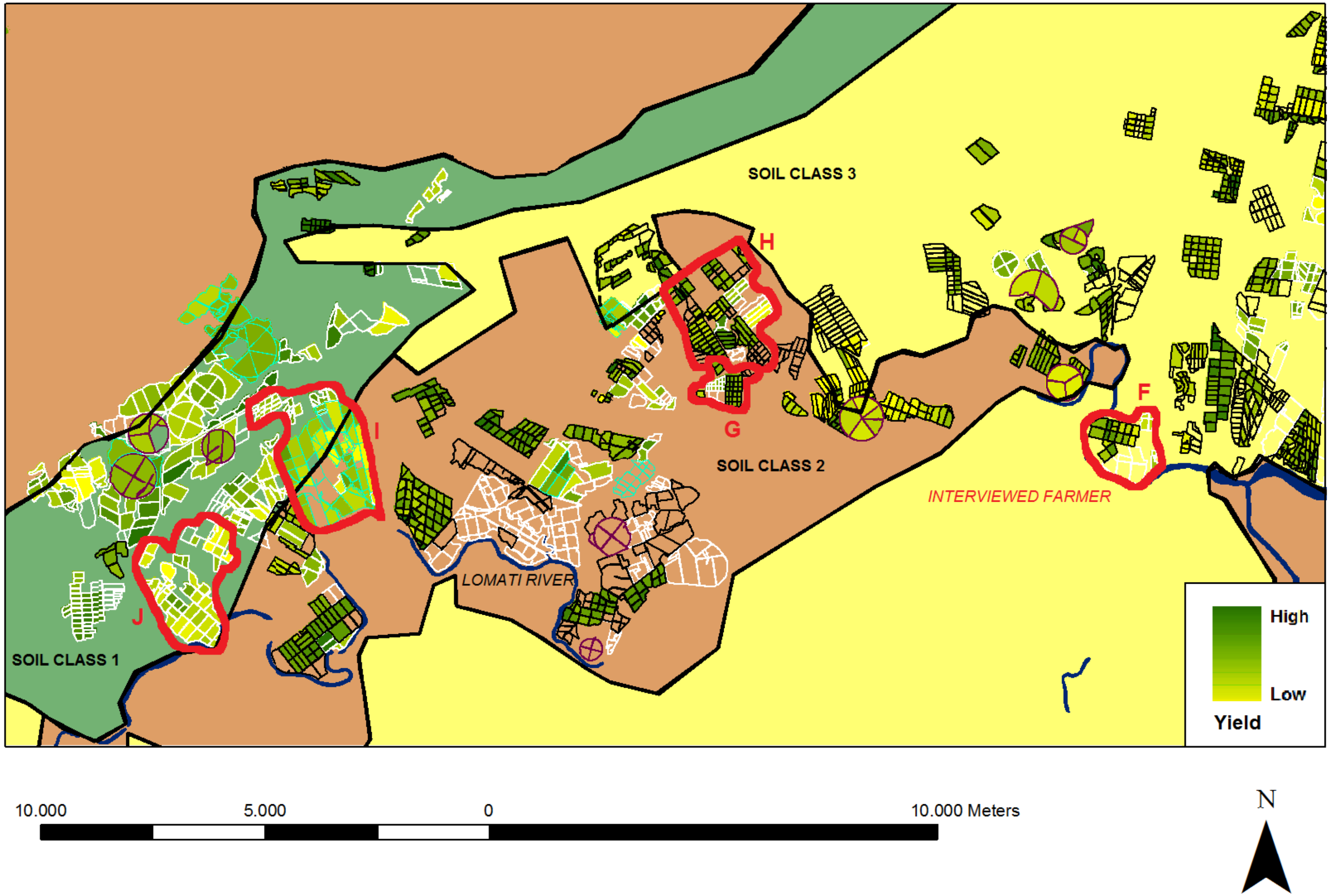


Figure 4.2: Overview of yield production for different farming typologies of commercial farmers on the Lomati River (see legend of figure 4.1). N.B. It was difficult to establish the exact water source of farmers in soil class 3. These farming typologies may be overlapping.

Average yields of commercial farmers have stayed relatively stable over the years with average yields of 94 ton/ha in 2004 and 98 ton/ha in 2007 (TSB, 2004; TSB, 2007). However, looking at the different farming typologies of the commercial farmers as presented in figures 4.1 and 4.2 it is clear that there are still differences in yield production within each farming typology. Looking at pivot irrigation within soil class 1 on the Komati River, for example, figure 4.1 shows that there are pivots with high values for yield production (green) and pivots with low values for yield production (yellow). This effect is similar for ET_a, biomass and CWP (Annex IV). It is obvious that there are optimal and sub-optimal farmers within each farming typology. As the physical characteristics of each typology are the same, the final diversity needs to be explained within the concept of the farming system (see conceptual framework). This will include factors such as water, fertility and crop management.

4.1.1 Analysis of Diversity of ET_a, Biomass, Yield Production and CWP within the Farming Typologies of Commercial Farmers

In order to find reasons for differences between optimal and sub-optimal farmers, ten (8%) commercial farmers were interviewed (Farmers A – J). These farmers have been outlined in figures 4.1 and 4.2 and are spread over the different typologies. Table 4.1 gives their general characteristics. The indicators of 'optimal' and 'sub-optimal' were perceived to be related to yield production in particular. Their level of yield as compared to other farmers can be seen in figures 4.1 and 4.2. It must be noted that these figures refer to the 2004/2005 season. The views and opinions of these ten farmers were taken together to discuss optimal factors and constraints for yield production in a general way, focusing also on the current (2008) situation. According to the sample of farmers there is one major reason for the differences between optimal and sub-optimal farmers: management. To produce cane you need to "feed it and weed it". Management is in turn related to farmers' commitment, attitude, motivation, knowledge, skills and responsibility. Differences between optimal and sub-optimal yield production were perceived to be related to management of finances, but also of fertilizers, herbicides, water, labour and fuel.

FARMER	A	B	C	D	E
Soil Class	1	1 / 2	1	1 / 2	1
Water Source	Komati	Komati	Komati	Komati	Komati
Irrigation Type	Pivot Drag Line Drip	Pivot Drag Line Drip Floppy	Drag Line	Pivot Drag Line Drip	Pivot Drip
Cane (ha)	218	2010	135	130	289
Cane Yield '08	Medium	Optimal	Medium	Medium	Medium
Other Crops (ha)	No	Bananas (400)	Mangoes (55)	Mangoes (10) Vegetables (30)	Citrus (4.5) Vegetables (5)
Management	Family Farm	Company	Family Farm	Family Farm	Family Farm
FARMER	**F**	**G**	**H**	**I**	**J**
Soil Class	3	2	2	1 / 2	1
Water Source	Lomati	Lomati	Lomati	Lomati	Lomati
Irrigation Type	Drag Line Drip	Drag Line Drip	Drag Line Drip	Drag Line Floppy	Drag Line
Cane (ha)	120	50	180	414	214
Cane Yield '08	Optimal	Medium	Medium	Medium	Sub-Optimal
Other Crops	Mangoes (40) Citrus (40) Lychees (10)	Mangoes (40)	No	Bananas (250) Mangoes (150) Lychees (20)	Bananas (93) Mangoes (12) Lychees (9) Vegetables (12)
Management	Company	Family Farm	Family Farm	Family Farm	Black Community

Table 4.1: Interviewed farmers and their general characteristics. N.B. Medium cane yield indicates that these farmers have both optimal plots (high yields) and sub-optimal plots (low yields). Optimal cane yield indicates high yields overall, sub-optimal cane yield indicates low yields overall.

4.1.1.1 Management

Finances

Over the years the profit margin of sugarcane has gone down due to increasing input prices. The increase in input costs seems to be an international issue that is affecting farmers worldwide. According to CANEGROWERS average input costs in the Lower Komati have risen with 44% over the past two years, while average income has only risen with 15% (CG-2, 2008). Nine of the interviewed farmers (all but Farm J) indicate to have a buffer income due to their relatively large land sizes, but they all perceive the so-called cost pinch to be a major constraint for optimal production. Fertilizers in particular are a major concern for these farmers. They indicate that prices rose about 50% during 2007/2008 and are now sometimes 300-400% of the initial price. They are struggling with these price increases, and indicate that all around them they see farmers going bankrupt. The ability to pay for fertilizers has forced five of the farmers to cut back their fertilizer applications from 100% to as low as 50%. This of course affects their soil fertility negatively, leading to lower values of yield production. The cost pinch makes farmers focus on managing their economic water productivity, rather than their crop water productivity in kg/m^3. All farmers indicate to use water where it matters most. They may favour certain crops over others, or favour a young sugarcane crop over an older one.

Fuel prices have been continuously rising to about 175% from 2006 to 2008 (Armitage, 2008) and are another point of frustration for the interviewed farmers. However, they are all located relatively close to the mill. They indicate that high transport costs mostly limit the farmers who are located beyond a certain radius (±30 km) from the mill. The commercial farmers in Barberton, for example, are located over 60km from the Malelane mill. These 200,000tons of cane supply (per year) pose a significant problem to TSB, as these farmers are especially affected by transport costs. The question remains if these farmers are really making money producing sugar. They might be better off producing other crops such as citrus or lychees. However, to protect the mill, TSB is subsidizing transport costs for these farmers for at least the near future. After that, other solutions will have to be found. TSB acknowledges that there will be structural problems in the future and that growers will discontinue farming cane. They believe that within five years there will be a situation of under production and sugar shortage (TSB-3, 2008).

Besides the rising input costs, all interviewed farmers are frustrated by the ongoing theft in the area. In addition, this theft has forced Eskom to increase electricity prices. The farmers complain about not being able to get insurance for electricity cables, and have resorted to all kinds of measures to reduce theft. Farmers G and H are least affected by theft, as their labourers all live near the pumpstations on their property and scare of the thieves. The pivot of Farmer D has been down for weeks due to theft of the electricity cables. This farmer has now replaced the copper cables with aluminium. Farmer B has hired guards who patrol all corners of the fields 24/7. The other farmers do not have guards or alarm systems, as they indicate that these systems are too costly and guards are unreliable. Moreover, due to their large landsize it will be difficult to actually catch a thief once the alarm sounds.

Around 40% of these farmers' input costs concerns their labour. Minimum wages were introduced five years ago, and are affecting their amount of labourers. These farmers were used to paying the labourers small money, supplementing that with meat and food rations from cattle and their other crops. However, these days, they need to pay their labour according to the law. The minimum wages are currently ZAR1091.00 per month or ZAR5.59 per hour (The South African Labour Guide, 2009). Nine of the interviewed farmers have cut down on their labour, and have resorted to more mechanization in order to save costs. Farm J doesn't employ any farm labourers anymore.

Half of the interviewed farmers complain about not being paid enough for by-products. Growers all get paid a coal value for the electricity the mills are generating, and they get paid for a share of the value of molasses that has been sold (SASRI-1, 2008). However, these farmers complain that TSB sells the molasses to TSB owned animal feed companies. TSB is thus the buyer and the seller, and these farmers accuse TSB of keeping the prices down. TSB counters this by saying that the commercial farmers just want more money in their own pockets (TSB-3, 2008). CANEGROWERS is assisting the farmers by trying to increase the shares the farmers receive for the by-products, but obviously gets resistance from TSB. This results in a continuous, annual struggle between the miller and the grower, which then results in status quo (CG-2, 2008).

Farmers' ability to gain access to capital influences their yield production as it affects their ability to buy fertilizers, to maintain their irrigation systems, and to replace stolen irrigation equipment. However, the way their capital is managed must not be overlooked. Farms B and F are managed by a management company. Farm J is managed by a black community, and the rest of the farms are family farms. Farmers B and F stress that, with all the financial challenges growers face, farmers need to stick to their budgeting and planning. They accuse the family farms of farming from day to day without keeping any records. They stress that farm data management is required for analysis and for making cost control decisions. To help them with this, farmers can make use of industry resources, such as the SASRI (South African Sugar Research Institute) training centre, or the economic advisors at CANEGROWERS. They indicate that in these tough times growers need to take stock of their operations and focus on the details, and manage their capital carefully. These two farms, that are considered 'optimal', accuse the other farmers of being spoilt. In an environment of high profit margins these farmers never really needed financial management skills, they say. Now, with the increase of input costs, these farmers are struggling and find out that their financial management skills are lacking.

It is true that the family farms are struggling more than the management company farms. Due to the cost pinch, family farms have come under significant pressure. In a way they do farm from day to day, as they do not know what the future brings. However, four of them have hired financial advisors to help them with budget planning. To survive, these farms need to take short-term action or adopt survival strategies to get their farming operation through the current economic crisis. Long term adjustments might include improved costing structures, efficient fertilizer applications, cheaper management costs or improved returns on management (J. Murray, 2008). Short term (survival) type adjustments may include selling portions of land, selling under-utilized equipment or restructuring debt. Struggling farmers may have to consider leasing out their farms, and look at making off-farm income. It is essential for them to reduce costs or increase revenue. One challenge for cane growers and local grower associations is related to bulk purchase groups. Taking this route may reduce the single highest input cost of fertilizers. The South African Sugar Association (SASA) is looking at reducing fertilizer prices by importing fertilizers directly and removing all the middlemen (CG-2, 2008).

Farm J is a different story, as this is an LRAD (Land Distribution for Agricultural Development) farm that is now managed by a black community. The yields of this farm are very low ('sub-optimal') compared to the other commercial farms. The crop looks neglected, and the manager explains that the property was already neglected when they took over. They were also very unlucky in their first years due to the drought. In the end their debts proved to be too high, and this farm has now been declared bankrupt. Due to this bankruptcy, Farm J does not have any farm labourers anymore and the crop is no longer being maintained. The few people left on this farm are working in the office (without pay) to take care of final administration.

Soil

Besides management of finances, management of land needs to be up to standards in order to produce adequately. Management of land is related to management of soil, water and crop. The optimal growers indicate that they are more committed to using their inputs such as fertilizers, but also herbicides, water, labour, and fuel, more efficiently. Farmers B and F are applying 100% of required fertilizers. They indicate that it is essential to not cut on required nutrients. Failure to supply the nutrients needed for optimal crop growth will result in sharp reductions in yield and thereby profits. Being managed by successfull management companies (that also manage lands elsewhere) these farms are obviously not struggling with finances like the family farms do. Two of the family farms also apply 100% of required fertilizers, as they argue that this will at least stabilize costs and benefits. These two farms also try to use more alternative nutrient sources, in particular organic products. These are less costly, but also improve soil health and soil productivity as the organic matter improves water infiltration, and in the case of sandy soils, water holding capacity (Rhodes, 2008) However, this is not without problems. As most dairy production is located in Gauteng, the local volume of manure is limited. Moreover, applying fresh manure might cause diseases in the sugarcane when it's not done in the right way. Farmers therefore need to have the right knowledge for applying fresh manure, e.g. by incorporating it into the soil (TSB-2, 2008). Due to financial constraints these two family farms focus particularly on in-field nutrient management. They pay particular attention to soil sampling, and match Nitrogen (N), Phosphorus (P) and Potassium (K) supplies to the varying crop growth-stage requirements for these nutrients. P deficiencies need to be corrected at planting as it is important for root growth. Fertilizer expenditure for ratoons should focus more on N and K nutrition (Rhodes, 2008). Farms B and F also focus on in-field nutrient management and are involved in precision farming. Farmer B takes soil samples every 100 meters. He is thus able to determine the fertilizer requirement of his soils very precisely, making sure not to over-apply any fertilizers.

TSB indicates that around 50% of all commercial farmers do not practice soil sampling correctly (TSB-2, 2008). These farmers apply the same amount of fertilizers to their whole field, which might lead to over-applications in certain areas. As fields often differ widely in fertility, using a 'blanket' fertilizer dressing may result in inefficient use of fertilizers on fertile fields, but also in sub-optimal yields on fields with severe deficiencies (Rhodes, 2008). Five of the interviewed farmers do not put 100% of the required fertilizers due to financial constraints. TSB stresses that soil test data can minimize input expenditure while maximizing yields, and is trying to communicate this to the farmers through an extension worker and by organizing grower days (TSB-2, 2008). The last farm, Farm J, is not applying any fertilizers at all, as it has been declared bankrupt, and managers are no longer maintaining the cane. As Farm J is no longer managing its cane, this farm will be disregarded in further analysis (i.e. the rest of this paragraph).

Water

The current poor economic conditions make growers manage their economic water productivity, rather than their crop water productivity in kg/m^3. All farmers stress that they are under increasing pressure to demonstrate that limited water resources for irrigation are being used efficiently. Farms B and F take care of their water management within three main areas. Firstly, they make sure that their irrigation system is performing according to the design specifications and recommended standards. Secondly, they follow an appropriate irrigation scheduling strategy, and thirdly, they reduce wasteful evaporation from the soil surface. Taken together, they indicate that these three measures result in reduced water and electricity charges, improved yields, and significant increases in profitability. These two farmers indicate that an irrigation system cannot be managed properly, unless the hardware is assessed and performing to a reasonable standard. Assessment involves taking and interpreting numerous infield measurements that include pressure at hydrants, sprinklers/emitters and lateral ends, and the variation in pressures between hydrants and sprinklers/emitters. These measures affect the amount of water applied per irrigation application and the rate and evenness of water application. Another important measurement concerns the nozzle wear. Maintenance is essential. Excessive nozzle wear will lead to uneven water applications, excessive water applications, reduced pumping efficiency, higher electricity bills and reduced yields. Amounts of water can also be lost through pipe leaks. It is important to evaluate the amount of water applied per irrigation application, and once this is known appropriate irrigation scheduling strategy can be derived.

Farms B and F are taking care of their irrigation scheduling, and hire experts to help them. They have knowledge on the exact crop water requirements, and care for not over- or under-applying any water. The other seven farmers also stress the importance of saving water, and four of them have also hired experts to help them. They search for appropriate irrigation scheduling strategies in consultation with SASRI extension and specialists. They use different scheduling tools which range from relatively simple instruments such as tensiometers, to more sophisticated methods that estimate soil water content through water budgeting. This way, they determine the amount of water and timing of application for maintaining soil water content in an optimum range. Besides water savings, this may also lead to an increase in crop water productivity. The last three farmers indicate to apply a standard 7mm/day as was taught to them by their parents or by an extension worker. TSB irrigation engineers indicate that the large storage facilities of commercial farmers sometimes lead to over-irrigating as farmers irrigate inefficiently with surplus water (TSB-2, 2008). These farmers believe that extra water will benefit the crop, but over-irrigation may wash out nutrients from the soil affecting the yield production. Under-irrigation may improve the CWP, but too much water stress will affect the yield production negatively.

Although all farmers acknowledge that water savings are essential, the family farms are more limited by finances than Farms B and F. This means that their maintenance sometimes suffers as they cannot always buy new parts to replace broken or stolen ones, and that breaks and leaks are not always fixed immediately. A year ago, Farmer A bought a second-hand pivot system, which broke down soon thereafter. As this farmer could not find spare parts soon enough, his yield production was hugely affected. Besides maintenance, the design of irrigation systems should be up to standards for good yield production. Farmers B and F hired adequate engineers to do the designs and paid for good work. Farmer A, who did not have the finances to implement the best irrigation designs ("If you buy baboons, you pay with peanuts") is now suffering from the consequences. He indicates that his driplines were placed on sloping lands, constraining the water flow.

Crop

When it comes to the crop, optimal farmers are able to find the resources to identify and implement best practices for sugarcane production. They may reduce the impact of mono-cropping, and use fallow periods, inter-cropping, and mulching where appropriate. Three of the interviewed farmers use sugarcane tops and trash for mulching on their fields irrigated by sprinklers. They are reluctant to cover their driplines, and do not use mulching for their pivots, as it causes problems for the rotation of the system. When used correctly, advantages of mulching include improved soil health (organic matter, micro-organism activity and nutrient status), better weed control, alleviation of post-harvest cane deterioration and the potential to reduce wasteful evaporation from the soil surface (J. Van Der Merwe, 2008). As evaporation is reduced, the irrigation water requirement and crop water demand also reduces. This will result in water and electricity savings. It must be noted that mulching also has potential disadvantages such as reduced crop growth rate and yield, higher harvesting and transporting costs, and an increase in insect pests such as trash caterpillar (J. Van Der Merwe, 2008). For soils with a higher clay-content mulching is not always an option as it will keep the soil temperature low. This will cause difficulties with re-growing the crop. These disadvantages cause the six other farmers to burn their cane tops and trash. This means that they need to remove all their driplines before burning. As environmental concerns are growing, the practice of burning is becoming a problem as it causes hot fires and smog. Good management of the fires is essential. After the drying off period, burning needs to be done as soon as possible or cane re-growth might be destroyed. Seven of the farmers (all but Farmers A and H) practice inter-cropping. They grow 3-month crops such as tomatoes, butternut, chillies and aubergines between the cane or in the fallow period. Beans are especially beneficial as they put N (nitrogen) back into the soil, and the 3-month fallow period is a sufficient time to kill diseases. All farmers take care in producing good quality seed cane, actively control pests and diseases, and make correct use of sugarcane varieties. As their plots may consist of many different soils, they may also grow a large number of different varieties based on soil type, but also on disease susceptibility and recovery, ratooning ability, weeds, harvest and transport friendliness, yield and Recoverable Value (RV) %.

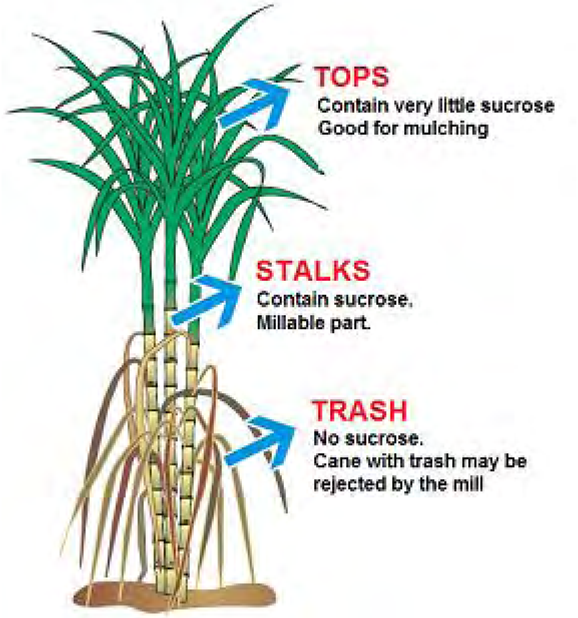


Figure 4.3: Sugarcane components (SASRI, 2008b).

The seven farmers who grow other crops besides sugar indicate that sugarcane is their subsistence crop. They grow cash crops, e.g. lychees, bananas and citrus, to make an extra income. Sugar is their security system, and they believe that “diversification pays in hard times”. However, diversification means that management of sugarcane may suffer in times of drought or financial insecurity. These farmers indicate that sugar is a very forgiving crop and is cheapest to re-establish. Vegetables for example need a higher labour input, and have higher risks associated with wind, hail, heat, rain and insects. In times of water restrictions, these farmers have to decide where to apply water to get the biggest benefit. Citrus, mangoes, lychees and bananas can sometimes make three times as much profit with the same water, and farmers will give priority to these crops. As farmers prioritize water delivery to their cash crops, this affects ET_a, biomass and yield production of their sugar crop negatively. Besides, farmers may also have sugarcane fields of different ages. Again, they will calculate how to get the most gains with less water, and try to make the best management decisions. The new crop will often get their priority as they rather irrigate a young crop over an old crop. As mentioned before, farmers are focusing on managing their economic water productivity, rather than their crop water productivity in kg/m^3.

Farmers A and H produce just sugarcane. They used to grow vegetables and bananas, but did not make enough profit. They found the marketing of other crops to be more uncertain and unreliable: "a gamble." As TSB offers a guaranteed market, these two farmers focus on sugar only, indicating that sugar is their 'stabilizer' which gives the best returns on the money invested. They argue that sugar is a low risk crop with quick returns (one year vs. six years for citrus or macadamia trees). They see sugar as their most secure investment, as it is "solid, structured, and organized". Because of the guaranteed market, they argue that sugar will always be able to give them an income, allowing them to make a budget and plan ahead.

Labour

Besides managing land and water, all farmers invest in labour management to improve productivity. They focus on farm training, supervision, and control. They train their labourers, and supervise them to prevent costly mistakes on e.g. herbicide applications. They recognize that good relationships with their labourers, and paying them their minimum wages, is important to have them do their job in a satisfactory way. Being hands-on, they claim to reduce on maintenance costs and waste, while improving their production processes. They make sure weed control is being done satisfactory, as fertilizers are too expensive to waste on weeds. Agro-chemical costs are rising, and weeds may cause a "production nightmare" when things go wrong. Optimal timing of application and adequate capacity help save costs due to less expensive products and reduced crop damage.

Due to rising labour costs, there has been an overall reduction in employment figures. All farmers have kept only their well-trained key personnel full-time. They use their existing force and identify and train replacements where possible. One farmer has sold part of his machinery, and now hires contractors for tasks as replanting and land preparation. He indicates that this saves him in fuel costs and is more cost effective per hectare. Farmer F stresses the point of knowing how to work with 'blacks'. He feels that he is doing better than the farmers around him, because these other farmers are looking down at their labourers and neglect the human aspect which is necessary for productivity of these labourers. This particular farmer prides himself in being able to talk to his labourers at grassroots level without putting in Western ideology. He claims to motivate his workers by speaking their language, and knowing their culture. He also pays his labourers more than the minimum wage which he believes is essential for good productivity. As there is pressure from the government to employ blacks, Farmer B is employing black graduates and trainees. Farmer B offers in-house training programmes for Black Empowerment (BE) purposes. In return he receives tax reductions. He stresses that having educated labourers will influence management of the farms positively. It will also transfer skills and uplift the community. The process however, is neither an easy one nor a fast one.

Machinery

All interviewed farmers own vehicles and machines for sugarcane production, and indicate that the increasing costs of vehicles, diesel, tyres, spares and maintenance have affected their financial situation negatively. They all claim that operating machines is very costly, and that it forms some of their highest expenses. The most effective way to limit the costs of machinery is to ensure that the machines are utilized effectively. The more hours a machine works in a year, the less the particular operation costs (Lyne, 2008). Two farmers who are located close together are limiting machinery costs by sharing equipment. This ensures that a machine is fully utilized during the year. They do regular benchmarking in order to be able to perform at best practice. One farmer has just replaced his 20-year old electric motors with more energy efficient models. Another farmer has resorted to making more use of contractors, just like the emerging farmers. The eight farmers using their own machinery indicate that a lot of time goes into maintenance of these vehicles. This sometimes limits their time for actually managing their farm, which may affect yield production negatively. Farmers B and F are an exception, as they have hired special employers for maintenance of their vehicles. They invest in preventative maintenance to avoid costly breakdowns and downtime. Monitoring their systems closely, they believe to reduce fuel consumption, accidents, maintenance and insurance costs.

4.1.2 External Factors Influencing the Commercial Farming Typologies

The previous paragraph explored management as an internal factor within the farming system, and the way it may influence ET_a, biomass, yield production and CWP within a farming typology. The interviewed commercial farmers indicate that management is the most important factor that needs to be improved to lift sub-optimal farmers to the level of optimal farmers. However, there is one important external factor that is also influencing the farming systems of the commercial farmers, and with that the diversity in ET_a, biomass, yield production and CWP. This external factor is related to land security and land claims.

4.1.2.1 Land Security

Land security is an important factor influencing management. About 70% of the commercial farmers in the Lower Komati have a claim on their land (CG-2, 2008; DALA-2, 2008), but it is common knowledge that the total sum of the Onderberg is under claim. “If you think you haven’t had a claim don’t be too relaxed, it is in all probability an administrative oversight (T.J. Murray, 2008).” The process of land claims lead to much frustration among both farmers and claimants. On the one hand, claimants get frustrated due to delays from the government and sometimes resort to land invasions. On the other hand, farm owners can no longer use their land as collateral for loans, and when they lack the incentives and/or money to continue working with their land, their land is often taken out of production and allowed to deteriorate.

Settled Land Claims

Once a claim has been settled, the land is transferred to the ‘black’ community. In many cases these people do not have a background in farming. Land claims pose a significant risk to the cane supply to TSB, but also to the Department of Agriculture (DoA) and the Department of Agriculture and Land Affairs (DALA), as fallow lands will not contribute to food security (DALA-2, 2008; DoA-2, 2008; TSB-3, 2008).

Once a claim has been settled, the consequences can be broadly divided into four scenarios. The first scenario concerns, among others, the Komatidraai and TenBosch farms which are located on fertile soils (soil class 1). When these lands were transferred to the community, TSB faced the prospect of losing a large percentage of its cane (TSB-3, 2008). As TSB could not afford to lose that good potential land and its cane, it started a joint venture with the farmers and took care of the management. TSB now farms that land together with the community and these two farms are amongst the top rated sugarcane farms in South Africa with high average yields close to 200ton/ha (TSB, 2007). These TSB estates are capital intensive sugarcane production systems with high levels of management input and control. TSB has a 20-year contract to manage these farms and the proceeds are split 50/50 (BT-2, 2008). The second scenario concerns community farms that are farmed by management companies. These are mostly on marginal to medium fertile soils (soil classes 2 and 3). For these lands the farmers have either appointed their own management company, or TSB has put a management company in place to keep the farms going and to secure a supply to the mill. Currently, there are about 12,000ha under management companies (BT-2, 2008).

Thirdly, it happens that a community links up with the commercial farmer who leases the farm back, trains the community for three years, and then guides them for another seven years. However, these joint ventures between commercial farmers and the community do not always go smoothly. There is a lot of mistrust from the community's side towards the white farmers and vice versa (EF, 2008; CF, 2008). One farmer summed this up nicely: "They think we are thieves and liars, we think they are idiots". In many cases there are troubles with working together, both parties get frustrated, and the commercials farmers decide to leave the area. They may take their cash and leave to Mozambique to farm there, and end up being competition to South Africa. Others start up their own private management company. Some just stop farming altogether, and may find a new job or enjoy their pension. This situation leads to the fourth scenario when lands that are not managed by TSB, the community, a management company or a commercial farmer, get abandoned. In this case the land is no longer productive and results in a loss of cane for TSB, and a loss of profit for the community. This is often the case with lands on marginal to medium fertile soils. These lands were farmed by commercial farmers who were happy to sell their land, as they had often been struggling financially. They saw an opportunity to leave their bad soils, get some cash, and do something else. When these lands were transferred to the communities with no knowledge on sugarcane farming, they went bankrupt and abandoned the farm. During the 2004/2005 season, a significant amount of these abandoned farmers were found in soil class 2 on the Lomati River. This can be a reason for the very low values of ET_a, biomass, and the zero yield production and CWP in this specific area.

Land Claims in Progress

Besides the abandoned lands, another important issue affecting management and cane production concerns farms with claims in progress. Nine of the interviewed farmers have a claim on their land. Farmer B is planning on leasing his own farm back after settlement of the claims and is farming at full speed. He keeps investing in his sugar. Even though the whole land claim process is plagued by insecurity, and might take years, this farmers chooses to keep his yields up and his income stable instead of doing nothing and waiting for the cash. Farmer F is another successful farm, even with land claims. He farms intensively, has shareholders, and is expanding. These two farmers do not want their farms to degrade as it will affect the valuation of the land. In other cases, however, the process of land claims leads to deterioration of farms, as farmers cannot get any loans, cannot sell the land, and lack incentives to keep working on their land. Farm H, for example is no longer focusing on improving production, but focuses on maintaining only. Because of the uncertainty, he is reluctant to invest capital in his farm, as he is not sure if he will get the opportunity to recoup it. This farmer has a full-time other job, and is waiting to sell the farm. He is frustrated by the delays of the land claims commission. Similarly, the actions of Farmer G are limited by a land claim. This farmer claims that he cannot plan ahead. He doesn't know for how long he will be staying and feels like he is farming "with an axe over his head". He is refraining from replanting (which is a major cost), is keeping a much longer ratoon than preferable, and brought down his fertilizer use. He is also irrigating his fields with a water canon, instead of a much more efficient, but more expensive, drip or sprinkler system. In order for their land not to use any value, some farmers keep up the appearance of a successful farm by replanting their plots with cheap (non-certified) seed cane, but in the end cases like these will become a problem for TSB, as it affects the cane quality (TSB-3, 2008).

Although not all farmers are happy about losing their lands, most farmers are willing sellers, and acknowledge that the land prices are reasonable. One non-willing seller states that he is forced into a 'willing seller' as the community is threatening to burn down his cane. It cannot be denied that the settlement procedure of land claims comes with delays and insecurity that may affect the production of cane negatively. Moreover, the land may lower in value due to inflation. Officials often attribute slow progress to high land prices and a lack of willing sellers (DALA-2, 2008; ICMA-1, 2008). However, the farmers indicate that redistribution is being slowed down by inexperienced officials and poor communications. There is some scepticism about the efficiency and the capacity of the land claims commission, as the commercial farmers believe they do not have the knowledge to handle land claims. An example concerns Impala Farm. A couple of years ago this farm was claimed and transferred to a local tribe. However, currently, another tribe is claiming the same land. This indicates that the commission did not process the first land claim properly, as it cannot guarantee the legitimacy of the first land claim (CF, 2008; CG-2, 2008).

4.2 EMERGING FARMING TYPOLOGIES

Similar to the commercial farmers, different farming typologies can be established within the farming system of the emerging farmers as well. It was already concluded that climate has a smaller influence on the diversity in ET_a, biomass, yield production and CWP of farmers than soil. Soil class proved to have a significant influence on values for ET_a and biomass of farmers, as these values decrease when the soil becomes more marginal and less water retentive. This is especially true for the emerging farmers, indicating that they have, overall, been struggling more with adjusting their irrigation systems to the marginal soils than commercial farmers. For emerging farmers, soil class is also a bigger constraint for yield production and CWP than it is for commercial farmers, indicating that commercial farmers have found better ways to adjust their management practices (e.g. application of fertilizers and weed control) to the more marginal soils. Similar to the commercial farmers, the range of values for ET_a, biomass, yield production and CWP of emerging farmers becomes larger for the more marginal soils, meaning that part of the farmers on marginal soils have found ways to adjust their irrigation frequency and management practices (e.g. application of fertilizers) to the soil type, while others have failed. Water allocations proved to have an influence on ET_a, biomass and yield production of emerging farmers, with an advantage for farmers on the Komati River. This indicates that, even with non-optimal irrigation systems, farmers on the Komati River are able to apply more water to their lands to benefit ET_a and biomass due to their larger water allocations. Irrigation type further influences yield production of emerging farmers. Drip systems yielded the highest values for yield production and CWP overall. Pivot performed better than drag line sprinklers which might be due to its larger drop size and less evaporation through wind displacement. A final factor affecting values of ET_a, biomass, yield production and CWP of emerging farmers concerns the design of the systems. Each scheme has its own design, with extra design difficulties for the 'seven projects'. All schemes are operated collectively, and farmers generally have to work together when it comes to operation and maintenance and irrigation scheduling. Chapter 3 set the base for the different farming typologies of emerging farmers. When classifying farmers according to soil class, water allocation, irrigation type and project scheme, many different farming typologies can be formed. For simplicity's sake one project will be treated as one typology (table 4.2). An overview of the projects can be found in Annex I.

Typology	Project	Water Source	Soil Class	Irrigation Type
1	Boschfontein I	Boschfontein Dam	3	Drag Line / Pivot
2	Boschfontein II	Boschfontein Dam	3	Drag Line
3	Buffelspruit	Lomati River	1	Drag Line
4	Figtree A	Komati River	2	Drag Line
5	Figtree B	Komati River	2	Drag Line
6	Figtree C	Komati River	1 / 2	Drag Line
7	Figtree D	Komati River	1 / 2	Drag Line
8	Langeloop I	Lomati River	2 / 3	Drag Line
9	Langeloop II	Lomati River	2 / 3	Drag Line
10	Lugedlane	Komati River	2	Drag Line
11	Madadeni	Komati River	2	Drag Line
12	Magudu	Komati River	2	Drag Line
13	Mangane	Komati River	2	Drag Line
14	Mangweni	Komati River	2	Drag Line
15	Mbongozi	Lomati River	2 / 3	Pivot
16	Mbunu B	Komati River	2	Drag Line
17	Mbunu C	Komati River	2	Drag Line
18	Mfumfane	Komati River	1	Drag Line
19	Middelplaas	Driekoppies Dam	3	Drag Line
20	Mzinti	Komati River	3	Drag Line
21	Ngogolo	Lomati River	2	Drag Line
22	Nhlangu East	Lomati River	2	Drag Line
23	Nhlangu West	Lomati River	2 / 3	Drag Line
24	Ntunda	Komati River	2	Drag Line
25	Phiva	Komati River	3	Drag Line
26	Schoemansdal	Driekoppies Dam	2 / 3	Drag Line
27	Sibange	Komati River	2	Drag Line
28	Shinyokana	Komati River	2	Drag Line
29	Sikhwahlane	Komati River	2	Drag Line
30	Spoons 7	Komati River	2	Drag Line
31	Spoons 7B	Masibekela Dam	2	Drag Line
32	Spoons 8	Komati River	2	Drag Line
33	Vlakbult	Lomati River	2	Drag Line
34	Walda	Komati River	2	Floppy

Table 4.2: 34 different emerging farmer typologies.

When it comes to the emerging farmers, TSB has seen a drop in yield. In 1998 small scale cane growers' yields were close to 110ton/ha (TSB-3, 2008). By 2004 this had dropped to 74ton/ha (TSB, 2004). Over the years the break-even point of sugar production for emerging farmers shifted from 60ton/ha to 80ton/ha (TSB, 2007) meaning that farmers now have to produce over 80ton/ha to make a profit. However, most farmers do not reach this break-even point as average yields currently lie around 63ton/ha (TSB, 2007). Growers' difficulties in the first decade have included a three year drought (2003 to 2005) and a flood in 2000 that effectively knocked out some schemes for up to nine months, and in some cases much longer due to flood relief funds taking time to come through (Cartwright, 2008a). What made matters worse was that the drought coincided with very low world sugar prices (TSB-3, 2008). This made it difficult for many growers to replant their cane, which is essential after eight to ten years. Similarly, annual fertilization had to be reduced by some farmers due to a shortage of funds during these years (Cartwright, 2008a).

4.2.1 The NIEP Technological Package

It must be noted that, different from the commercial farmers, the farming system of the emerging farmers depends heavily on the technological package provided by the Nkomazi Irrigation Expansion Programme (NIEP). NIEP started the initiative to promote small scale sugar farming by black farmers and took care of the required inputs. The Malelane Mill (with a current capacity of 1.8 million tons per annum) was supplemented in 1997 by the larger Komati Mill with a capacity of 2.4 million tons per annum (TSB-3, 2008). As mills have to work at optimum levels to be profitable, there has been considerable pressure on the government and on financing agencies to get additional sugarcane growing in the area (Cartwright, 2008a). In 1993, the ZAR180 million NIEP transformed 7,094ha of previously under utilized land into 960 farming ventures (MBB, 1997). Over the years, this number extended to the 1500 current smallholder farming ventures spread over 9,800ha (TSB, 2007). The Mpumalanga DoA initiative was funded by the Development Bank of South Africa (DBSA) and the Land Bank. The development agent (Mpumalanga Development Corporation) appointed MBB Consulting Engineers to design the East side and act as project managers. They were aided by social and environmental consultants from ACER (Africa) (MBB, 1997). ACER was involved in lengthy ongoing negotiations with the local tribal chiefs and authorities, finding out the exact nature of the social and political landscape, and in drawing up and finalizing the plans. The West side of the projects were designed by Duplessis & Burger Engineers (DoA-1, 2008).

NIEP was conceived as a result of the granting of 7200ha of water rights to the Ka Ngwane government, the establishment of the ZAR600 million Komati Sugar Mill by TSB, and the issuing of sugar quotas to small growers (MBB, 1997). Construction of the Komati Mill only started after the planting of enough hectares was committed to by government and growers (Cartwright, 2008a). The area served by NIEP consisted of tribal lands under four chiefs. Land was given to the farmers by the tribal authorities. Chiefs decided on plot sizes and selected the farmers. These had to pay a joining fee of ZAR1000, and now have a 99-year RTO (Right to Occupy) (EF, 2008; TA, 2008). Many switched from other crops (e.g. mealies, cotton, bananas and vegetables) to sugarcane. Others just thought it important to have a piece of land of their own (this included businessmen and pensioners) (EF, 2008). People were excited about the development project as it came with a guaranteed market and an irrigation system. Before NIEP, farmers had to depend on rain and were struggling to market their crops. These people had already expressed a strong desire to supplement their subsistence farming with irrigated sugarcane production (Cartwright, 2008a). Subsistence farming had forced many of the men to go elsewhere to find work. Even today, 65% of the growers are still women (TSB-3, 2008), indicating that men still have to look elsewhere to earn a living.

In each project, project committees were formed who, with input from the consultants, identified the development area, recommended farm sizes, and selected the type of irrigation system. Due to the lack of support services in the area, and the fact that farmers had little experience with irrigation, the system had to be easily managed and require minimum maintenance. It also had to be flexible enough to irrigate other crops if farmers ever wanted to diversify. ACER claims that people fully participated in all stages of the decision making process (MBB, 1997) but as newly appointed farmers had no technical knowledge on irrigation schemes and sugarcane farming the truth in this may be questioned. Especially as most emerging farmers indicate that they had no clue what was going on at the time. “We saw tractors ploughing, sugar being planted, pumps being built, and then we were presented with a bill (EF, 2008)”. The engineers designed dams, weirs, pump stations, irrigation systems and energy centres. They developed and implemented strategies for land preparation, putting up fences, laying pipes and building roads. Bulk infrastructure was supplied for by the government. Government grants included the installation of pipelines, erection of perimeter fences, building of canals, construction of roads, bush clearing and the construction of pumping stations and farm buildings. NIEP also brought the benefits of electrification and water on tap to the area (DoA-1, 2008, MBB, 1997). The irrigation system was financed by MADC (Mpumalanga Agricultural Development Cooperation). The engineers employed small contractors throughout the process and created job opportunities to benefit emerging contractors. For quality control, prospective farmers who had an interest in having good quality work being carried out were employed as quality controllers (MBB, 1997).

DBSA • Concessionary loan funding for major infrastructure (Phase I) • Development framework • Facilitation of processes between stakeholders	**Provincial Government (DWAF/DoA)** • Political commitment • Line department coordination and communication • Financial support • Policy guidelines • Extension (DALA) • Coordination of design • Water quotas (DWAF)	**TSB** • Guaranteed market – sugar quotas • Provision of infrastructure – the sugar mill • Training and extension • Administrative capacity • Organization, coordination and logistics • Technical support (free technicians) • Social services (schools, clinics, soccer cup) • Access to loans (Akwandze) • Financial advice (Akwandze)
Land Bank • Concessionary loan funding for major infrastructure (Phase II) • Access to loans	**Local Government** • Political commitment • Coordination of priorities • Interaction with traditional authorities	**Research Sugar Experiment Station (SASEX)** • Agronomical information • Research and technology • Training
NGO Sector • Donor grant funding • Community development • Water provision to communities	**MADC** • Implementing agent • Production credit to small farmers • Coordination of irrigation system • Coordination of implementation • Administrative capacity	**SASA** • Institutional support • Information analysis • Industry structure and pricing • Training and extension (SASRI) • Negotiation, facilitation, lobbying and judicial support (CANEGROWERS)
FAF • Establishment costs • Production credit to small farmers • Financial training	**Support Institutions** • Technical planning, implementation and support • Socio-economic process development • Input supply • Entrepreneurial development • Electricity supply • Water supply • Engineering services (MBB, Duplessis & Burger) • Social and environmental consultants (ACER) • Contractors	

Table 4.3: Overview of the major players involved in NIEP (BT-2, 2008; CG-2, 2008; ICMA-2, 2008; MBB, 1997; TSB-3, 2008).

Part of the development costs were covered by several NGOs in the form of grants. Another part of the development costs were to be retrieved through the farmers themselves (TSB-3, 2008). The sugar industry contributed to post-development funding in the form of the Financial Aid Fund (FAF). Farmers received an initial production loan (around ZAR60,000) through Akwandze or FAF to pay for inputs such as labour and fertilizers. Training in basic agriculture was provided by community development officers (MBB, 1997). TSB and FAF contributed in training the farmers. Later, SASRI and DALA became involved with extension work. The government was responsible for communication and support structures for the farmers. Up till 2000, the government took care of the maintenance of the system, making sure everything was in good condition. In 2000 these tasks were handed over to the farmers themselves (TSB-3, 2008). An overview of the mix of players, including financial institutions, the sugar industry, government and support companies that were involved in NIEP can be seen in table 4.3.

4.2.2 Analysis of Diversity of ET_a, Biomass, Yield Production and CWP within the Farming Typologies of Emerging Farmers

In order to find reasons for the final diversity in ET_a, biomass, yield production and CWP, 5% of the emerging farmers all over the projects (and typologies) were interviewed. 71 farmers were interviewed individually and the views and opinions of these farmers will be discussed in this paragraph. Farmers perceived their main indicator of being 'optimal' or 'sub-optimal' to be their yield production. This parameter was therefore used to group the farmers. Farmers above the break-even point were mainly asked about optimal factors for yield production, farmers below the break-even point were mainly asked about constraints for optimal yield production. Table 4.4 shows an overview of the 71 interviewed emerging farmers arranged according to their yield production.

Table 4.2 presented the different farming typologies of emerging farmers. Figures 4.4 and 4.5 visualize these typologies and give an overview of yield production of emerging farmers on the Komati and Lomati Rivers respectively. Maps of ET_a, biomass and CWP can be found in Annex V. It is clear that each farming typology has optimal and sub-optimal farmers when it comes to yield production. Walda, for example has plots with high yields (green), plots with low yields (yellow) and plots with zero yields (clear). This effect is similar for ET_a, biomass and CWP (Annex V). It must be noted that these figures represent the 2004/2005 season. The views and opinions of the 71 interviewed emerging farmers were taken together to discuss optimal factors and constraints for yield production in a general way, focusing also on the current season (2008). Opinions of other stakeholders have been added as well. Moreover, this paragraph will discuss factors that can improve within the different farming typologies, such as water, fertility, and crop management, in order to transfer sub-optimal farmers to optimal farmers.

4.2.2.1 Farmer Background

During NIEP development, tribal chiefs appointed sugarcane plots to beneficiaries. At the time of development it was recognized that the farmer selection process was probably not ideal. It was recognized that subsistence farmers may not be farmers at all. Rather, they are supplementing their income with food production out of necessity. (Cartwright, 2008a; TSB-3, 2008). Only two of the interviewed emerging farmers had any experience with sugarcane farming before NIEP as they were farming sugarcane in Swaziland.

#	PROJECT	Area (ha)	Soil Class	Irrigation Type	Water Source	Yield (ton/ha)	Yield category
1	Ngogolo	7.1	2	Drag Line	Lomati	0	zero
2	Nhlangu East	1.9	3	Drag Line	Lomati	0	zero
3	Buffelspruit	7.6	1	Drag Line	Lomati	0	zero
4	Mangane	9.3	1	Drag Line	Komati	0	zero
5	Mbunu B	7.5	2	Drag Line	Komati	0	zero
6	Mbunu B	7.5	2	Drag Line	Komati	0	zero
7	Ntunda A	6.6	2	Drag Line	Komati	0	zero
8	Figtree B	12.8	2	Drag Line	Komati	0	zero
9	Buffelspruit	7.3	1	Drag Line	Lomati	15.54	low
10	Lugedlane	10.0	2	Drag Line	Komati	22.90	low
11	Boschfontein I	10.0	3	Drag Line	Boschfontein Dam	23.74	low
12	Mfumfane	6.8	1	Drag Line	Komati	24.64	low
13	Mzinti	7.0	3	Drag Line	Komati	25.15	low
14	Mangane	9.3	1	Drag Line	Komati	28.97	low
15	Mzinti	7.2	3	Drag Line	Komati	30.54	low
16	Nhlangu West	1.8	2	Drag Line	Lomati	32.32	low
17	Phiva	7.4	3	Drag Line	Komati	34.84	low
18	Boschfontein I	10.1	3	Pivot	Boschfontein Dam	35.86	low
19	Mbunu C	4.4	2	Drag Line	Komati	36.21	low
20	Ntunda A	6.9	2	Drag Line	Komati	39.14	low
21	Spoons 8	5.1	2	Drag Line	Komati	39.97	low
22	Mbongozi	5.8	3	Pivot	Lomati	40.39	below average
23	Boschfontein I	11.1	3	Drip	Boschfontein Dam	41.78	below average
24	Spoons 8	15.8	2	Furrow	Komati	41.81	below average
25	Mangweni (coop)	7.0	2	Drag Line	Komati	?	below average
26	Shinyokana	22.6	2	Drag Line	Komati	46.30	below average
27	Figtree C	7.8	2	Drag Line	Komati	46.74	below average
28	Sibange	7.3	2	Drag Line	Komati	47.68	below average
29	Boschfontein II	10.7	3	Drag Line	Boschfontein Dam	47.94	below average
30	Walda	11.5	2	Drip	Komati	51.68	below average
31	Walda	10.2	2	Floppy	Komati	53.01	below average
32	Spoons 7	8.9	2	Drag Line	Komati	55.39	below average
33	Spoons 7B	15.5	2	Drag Line	Masibekela Dam	56.61	below average
34	Phiva	7.7	3	Drip	Komati	57.26	below average
35	Phiva	8.4	3	Drag Line	Komati	61.23	average
36	Sikhwahlane	6.7	2	Drag Line	Komati	61.48	average
37	Magudu	8.1	2	Drag Line	Komati	61.49	average
38	Langeloop I	8.8	2	Drag Line	Lomati	62.65	average
39	Mfumfane	6.5	1	Drag Line	Komati	65.92	average
40	Madadeni	7.0	2	Drag Line	Komati	66.93	average
41	Mbongozi	6.1	3	Pivot	Lomati	67.64	average
42	Mbongozi	5.3	3	Pivot	Lomati	67.64	average
43	Sibange	7.2	2	Drip	Komati	68.92	average
44	Madadeni	10.0	2	Drag Line	Komati	69.13	average
45	Ngogolo	8.9	2	Drag Line	Lomati	69.32	average
46	Mbunu B	6.1	2	Drag Line	Komati	69.79	average
47	Mbunu B	5.7	2	Drag Line	Komati	71.80	above average
48	Figtree D	3.7	2	Drag Line	Komati	75.04	above average
49	Sikhwahlane	6.9	2	Drag Line	Komati	77.82	above average
50	Langeloop I	7.9	3	Drag Line	Lomati	78.58	above average
51	Mbongozi	5.5	3	Pivot	Lomati	79.18	above average
BREAK-EVEN LINE							

Table 4.4: Overview of the 72 interviewed emerging farmers spread over all typologies, arranged according to their yield production.

Table 4.4 continued.

BREAK-EVEN LINE							
52	Phiva	6.7	3	Drag Line	Komati	81.01	above average
53	Madadeni	7.0	2	Drag Line	Komati	83.27	above average
54	Figtree D	4.3	2	Drag Line	Komati	83.86	above average
55	Ngogolo	7.7	2	Drip	Lomati	84.57	above average
56	Figtree C	7.7	2	Drag Line	Komati	86.18	above average
57	Magudu	8.0	2	Drag Line	Komati	87.57	above average
58	Figtree B + D	29.1	2	Drag Line /Drip	Komati	88.99	above average
59	Magudu	7.6	2	Drag Line	Komati	89.42	above average
60	Mbunu B	6.2	2	Drag Line	Komati	90.37	high
61	Boschfontein II	10.2	3	Drag Line	Boschfontein Dam	90.60	high
62	Mfumfane	9.9	1	Drag Line	Komati	100.40	high
63	Buffelspruit	9.1	1	Drag Line	Lomati	102.77	high
64	Nhlangu East	1.5	2	Drag Line	Lomati	106.49	high
65	Mbunu C	6.9	2	Drag Line	Komati	106.62	high
66	Lugedlane	12.6	2	Drag Line	Komati	115.03	high
67	Lugedlane	18.6	2	Drag Line	Komati	123.28	high
68	Nhlangu West	1.9	2	Drag Line	Lomati	126.64	high
69	Spoons 8	8.4	2	Drag Line	Komati	127.07	high
70	Walda	9.9	2	Drip	Komati	127.29	high
71	Langeloop I	7.0	2	Drip	Lomati	129.88	high

All 71 farmers indicate that they saw NIEP as an opportunity to get out of the poverty trap and that they wanted to have their own piece of land. 37 of the interviewed farmers are currently above 60 years of age. These are all pensioners who all claim to enjoy farming, as it gives them something to do. Before the start of NIEP, 30 of them were subsistence farmers growing mealies, cotton and vegetables. The other 7 had jobs varying from policemen to shop owners to businessmen. Of the 34 farmers below 60 years of age, 21 were subsistence farmers before the start of NIEP. The other 13 had jobs varying from teachers to bricklayers to electricians and salesmen. This indicates that indeed, most farmers did not have any experience with commercial sugarcane farming. The four main reasons mentioned for joining NIEP are:

1. NIEP came with a guaranteed market, while the market for other crops was uncertain;
2. The government presented the people with an attractive development plan;
3. NIEP came with an irrigation system; and
4. People were looking for something to do after retirement.

The low overall yields of emerging farmers may indicate that NIEP developers overestimated the risk and hard work sugarcane production involves for these people. Farmers therefore have to be committed to make it work. Even though most of the interviewed farmers are considered to be sub-optimal as they are below the break-even point, 40 of these farmers consider themselves to be good managers. They stress that the problems they're facing are not their fault, as these are related to the drought, bad soils, break-downs of irrigation systems and theft. They believe that their low yields are not due to a lack of skills or commitment, but because of their lack of finances. Even with low yields, none of them want to go back to growing mealies or vegetables, or sell their piece of land. They claim to depend on the irrigation system and the guaranteed market of sugar, as they lack in their capacities to find markets for other crops. They just keep farming, and are praying for better times. 11 of these sub-optimal farmers admit that their management practices are lacking. These farmers are having financial difficulties, but they also admit that they are lacking in skills. These farmers indicate to want to learn more about irrigation scheduling, weed control, application of fertilizers and the taking of soil samples in particular.

OVERVIEW OF FARMING TYPOLOGIES OF EMERGING FARMERS ON THE KOMATI RIVER

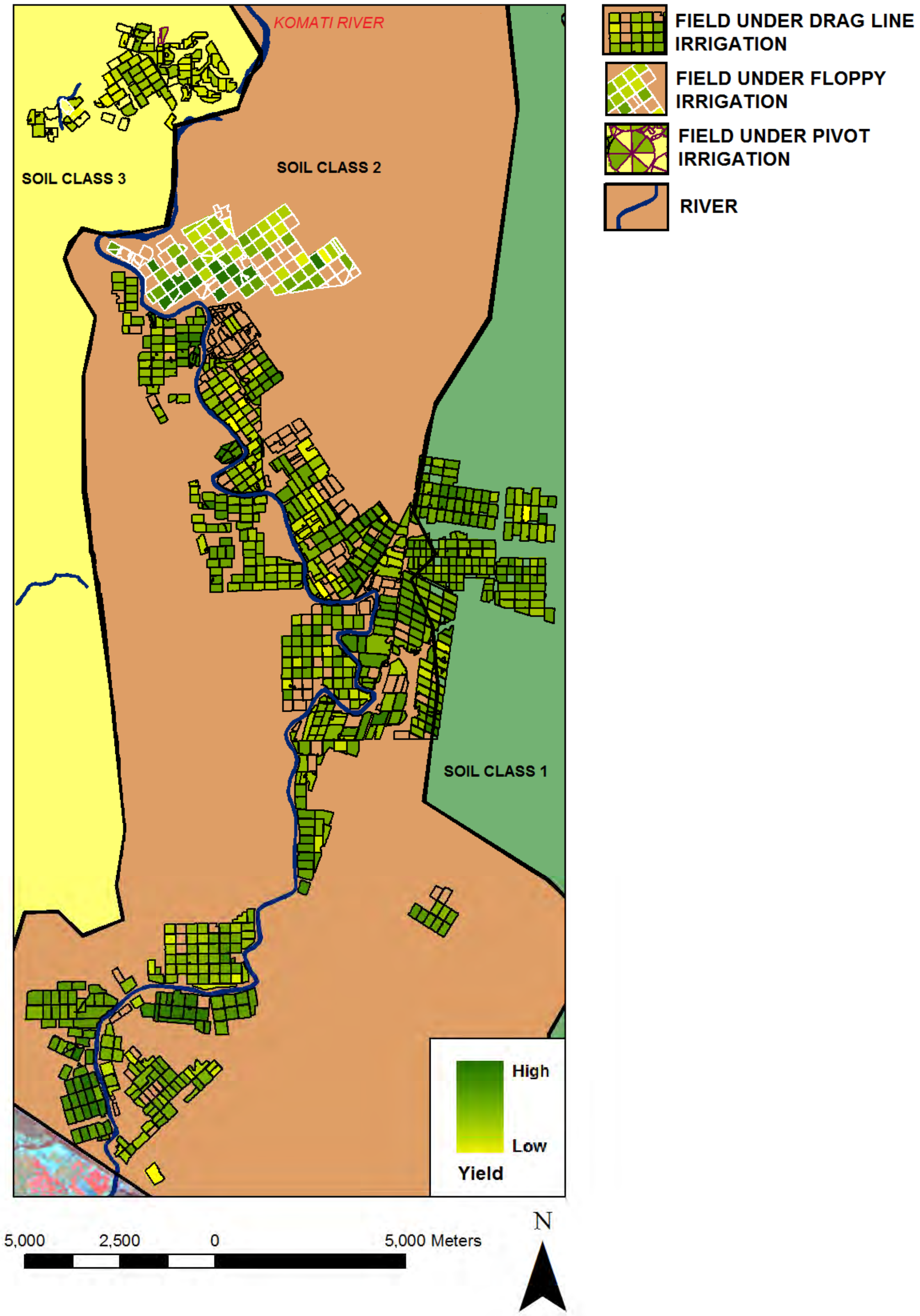


Figure 4.4: Overview of yield production for different farming typologies of emerging farmers on the Komati River.

OVERVIEW OF FARMING TYPOLOGIES OF EMERGING FARMERS ON THE LOMATI RIVER

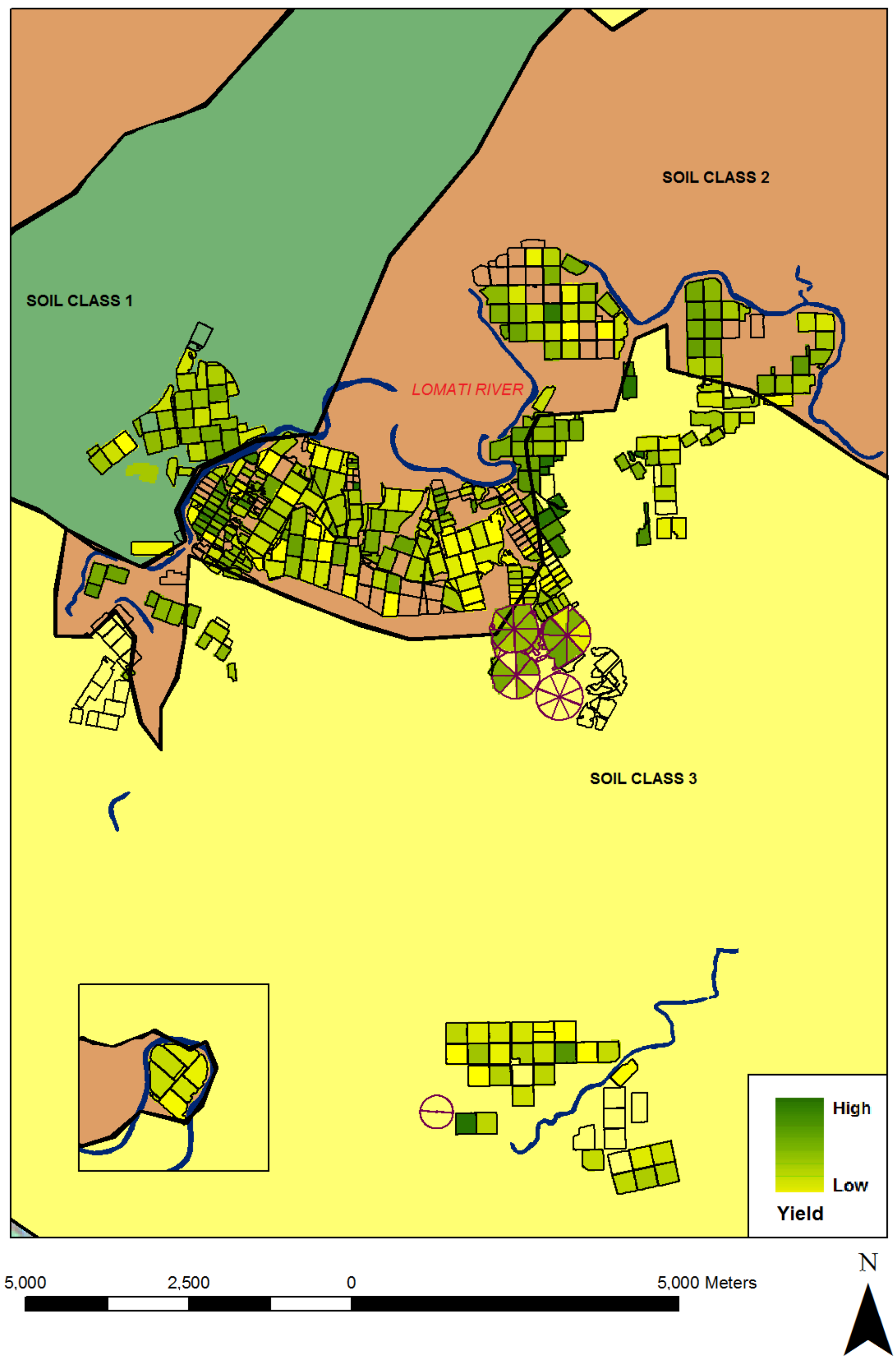


Figure 4.5: Overview of yield production for different farming typologies of emerging farmers on the Lomati River (see legend figure 4.4).

The 20 farmers producing above the break-even point claim that differences between sub-optimal and optimal farmers depend mostly on management and commitment. Even though these farmers do not have a background in sugarcane production either, they stress the fact that they are better managers than the sub-optimal farmers. The aspect of management will be further discussed in paragraph 4.2.2.3.

4.2.2.2 Access to Capital

A major constraint for optimal yield production among emerging farmers is perceived to be the lack of finances to invest in the farm. 31 of the interviewed farmers mentions ‘money problems’ to be their number one problem, while 27 farmers indicate it to be their second major problem, closely following the problem of water restrictions. The farmers’ lack of finances is perceived to be directly related to the major increases in input costs. Similar to the commercial farmers, emerging farmers are suffering due to the increase in input prices of fertilizers, electricity, transport and labour. The theft of cables affects their financial situation even more. The biggest challenge however seems to be in the debts of the emerging farmers.

Debts

Due to their small plot sizes, emerging farmers generally do not have a buffer income. They receive income from sugar once a year and need to produce over 80ton/ha to make a living. Of the interviewed farmers, only farmers #58 and #71 indicate to have substantial savings. Farmer #58 has 29.1ha of land, and has always been a successful farmer. He is working as a manager consultant for other farmers, which gives him an extra income. However, as he has been busy with helping other farmers, his own yields have deteriorated. Even so, he is still producing above break-even point, and is putting his consultancy job on hold to focus on his own farm again. Farmer #71 is producing very high yields on his 7ha plot. He owns a successful taxi-business, and has a wife who works as a teacher. Their double income allows them to hire a professional manager to manage their cane, while they are busy with their day jobs.

Around 10% of the interviewed farmers indicate to have family members contributing to their income, but most claim to be the ones having to support their family. Even so, all 71 farmers claim to rely on loans. Farmers #32, #33 and #63 are the only three farmers claiming to be debt free. They are all in their seventies, and claim that they are too old to receive loans from Akwandze. They use their retention money and pensioners grants to invest in their fields. Farmers #63 does not have access to loans, but is producing high yields. He has a wife who works as a teacher, and part of her income goes into the farm. He indicates that his good yields are due to his hard work and good management. This farmer is always on his land, and monitors his workers closely. Farmers #32 and #33 do not have the financial resources to hire labourers, and have to work on their lands themselves. Due to their old age, they struggle to manage their entire plot correctly. They indicate that they do not have the time to weed the entire field, and that they cannot move the draglines by themselves. Farmers #58 and #71 are both successful farmers who do have debts at the moment. However, they rely on relatively small short-term loans only. These loans help them to pay for fertilizers. These two farmers are wary of long term loans, as they do not want to pay for the high interest rates, and they do not want to lose all their income after harvest.

Even though all farmers claim to rely on loans, access to loans is difficult for emerging farmers. Their RTO means that they cannot use their land for collateral. However, there are three main financiers who are willing to provide development financing for people with a higher risk profile. Over 70% of the farmers do business with Akwandze, the rest is involved with Land Bank and MADC. These banks are willing to give out loans to farmers, but are reluctant to help farmers with low yields (AKW, 2008; LB-1, 2008). This means that farmers producing above the break-even point are more likely to receive loans than farmers below the break-even point, meaning that optimal farmers will have more finances available to invest back into their farms leading to potentially high yields again. At the same time, farmers with low yields are struggling to get loans. This puts them in a downward spiral as they lack money to invest in the farm making future yields even lower. Farmers doing business with Land Bank complain that this bank sometimes takes four months to approve a loan, during which their land deteriorates. Farmers #32 and #33, who have shares with Akwandze, complain about this bank refusing to give them loans. These two farmers are in their seventies, and are refused loans because of their old age. These farmers feel let down by the company they invested in, and have to use their pension money to invest in the farm. The only way for them to receive a loan is when they transfer their growercode to one of their kids. However, these two farmers are reluctant to do so, as they are afraid that their kids will take off with the money. It is clear that access to capital influences yield production of farmers, as it indicates their level of investment (e.g. fertilizers) into the farm. Farmers who are financially struggling may also neglect their irrigation system maintenance and general management.

The Seven Projects

The seven projects are a different case altogether when it comes to debt, and there is a relatively large amount of sub-optimal farmers within these seven projects. There is a ZAR60 million debt for the development costs, which is shared by all farmers of the seven projects. The farmers of Langeloop II are especially bad off with debts of ZAR40,000/ha (LB-1, 2008; LB-2, 2008). People at TSB and DoA believe that these huge debts are related to flaws within the NIEP development. The development costs of the seven projects consisted of grants and loans. The loans were carried by Land Bank, and Land Bank is now blamed for these debts, being accused of letting money ‘disappear’. Another scapegoat is Duplessis & Burger because of their supposedly ‘bad’ designs and poor development of the projects. People at TSB and DoA make the point that good commercial land could have been bought with the money that was spent on the seven projects.

Land Bank acknowledges that mistakes have been made during development of the seven projects, but denies that any money went missing. It argues that it is merely a financier with limited experience in farming. The people at the Land Bank office in Nelspruit claim that they did not know what was expected of them when they were approached by the designers. Due to the high risk of doing business with farmers and the high development costs, the Land Bank office in Nelspruit was initially hesitant to provide any funding. They now accuse the engineers and the task team of going behind their backs to the head office in Pretoria where the loan was approved without any individual assessment (LB-1, 2008; LB-2, 2008). Land Bank Nelspruit claims that the head office never considered whether the farmers were able to pay back their loans. Moreover, a feasibility study was done based on a yield of 100ton/ha (LB-2, 2008). Nowaydays, farmers are struggling to even reach the break-even point of 80ton/ha. Currently, 77 (of all 268 farmers involved with Land Bank) are still paying back their loans, the rest is failing (LB-2, 2008).

Duplessis & Burger also deny the allegations that money went missing. They argue that they only paid people for properly doing their jobs. They claim to have checked and signed all the invoices before payment and that nothing was going on ‘under the table’ (DB, 2008).

Duplessis & Burger maintain that they estimated the maximum development costs on ZAR20,000/ha, a loan amount with which farmers should still be able to make a living (DB, 2008). However, the developers felt forced by the chiefs to use certain soils, which complicated things. Langeloop II, for example, had a lot of rocks. As rock removal escalated, loans went over ZAR25,000/ha. At that point Duplessis & Burger tried to stop development, knowing that the farmers would struggle to pay back the money. However, as the farmers' committee had the last call, the project was continued. The farmers, understandably, wanted a clean piece of land. Extensive rock removal thus greatly increased the cost of the projects. The farmers themselves didn't realize the consequence of this development at the time. They admit that they had no clue. They do not know what the money was spent on and just signed all the papers, looking forward to their own piece of land.

In the end, more than 2000 people are directly involved with these Land Bank debts (268 farmers and their families (±8 people per household)). Land Bank takes part of the responsibility, acknowledging that not all beneficiaries were suitable for farming (LB-1, 2008; LB-2, 2008). Land Bank is currently in negotiations with CANEGROWERS about the debts, looking for a middle ground between the growers and the bank (CG-2, 2008; LB-2, 2008). Unfortunately negotiations are hampered by staff changes within Land Bank, delaying the process. But even if Land Bank will write part of the loans off, people will most likely still struggle with the remaining debt. It is clear that funds need to be raised. Farmers of the seven projects are hoping for the South African government to help with grants. DoA and TSB are pinning their hopes on overseas grants. Even when farmers' debts are cleared, it needs to be stressed that new (financial) management is important. Farmers need to learn how to deal with loans or they might find themselves in a downward debt spiral once again.

Net Income

Sugarcane is seen as an ideal crop for an emerging grower as the farmer receives advice and back up from extension officers and technical staff, e.g. free labour on pump repairs. The farmer does not have to harvest or transport the cane to the mill because this work is done by contractors (Cartwright, 2008a). However, the cost of contractors, irrigation repairs, water and other necessary expenditures will eat up some of 50% of the total income received from cane (Cartwright, 2008a; EF, 2008). As described above, most emerging farmers are depending on loans. Because of the contract the farmers signed with Land Bank and Akwandze, these banks are allowed to take the entire income of the farmers after all other deductions (e.g. for transport, electricity and fertilizers) have been made (AKW, 2008; LB-1, 2008). This means that 36% of all emerging farmers literally end up with a zero income (AKW, 2008). Adding to this problem is the 16-18% interest (AKW, 2008; LB-2, 2008) the farmers have to pay. Of the 71 interviewed farmers, 60 indicate to receive a zero income from sugar. Somehow, these farmers have to survive twelve to fourteen months without income, which means that the lessons carefully taught by extension officers about irrigation, fertilizers, and replanting have to be ignored, hence the drop in yields.

As emerging farmers are struggling with debts and many end up with a zero income, TSB has set up retention funds for these farmers. For each ton/ha the farmers produce, Akwandze saves ZAR60 which the farmers can use to invest back in the field (AKW, 2007). However, with the general decline in yield the retention fund naturally goes down as well, limiting the farmers in investing back into their fields. Moreover, due to their zero net incomes, farmers often use the retention fund for household matters such as food, schooling and furniture. All in all, this limits the options of the farmers to invest back into their sugar, negatively affecting the yield. All 60 farmers with zero incomes and declining retention funds claim that their financial troubles keep their spirits down. They indicate to be working for the banks, and especially Land Bank is seen as a big enemy. The general feeling of these farmers is one of discouragement, and they all claim to be losing their drive to farm. The general feeling of these 60 growers is that if they are to survive they will need subsidies from time to time on electricity, fertilizers, and above all, on replanting. They believe that loans should be made definitely repayable and be interest free for the first five years. Moreover, loans should be approved far quicker. TSB and DoA would like to see an additional ZAR30-50 million granted by the government to change or upgrade some of the inadequate irrigation systems put in. Applications have been made to the CASP (Comprehensive Agricultural Support Programme) fund for some two years now, but these have so far enlisted no response (Cartwright, 2008a; TSB-3, 2008)

11 of the interviewed farmers receive an yearly income ranging from ZAR4,000 (Farmer #64) to ZAR150,000 (Farmer #66). Farmer #64 has a very small plot of 1.5ha and is producing very high yields. Even so, she perceives her plotsize to be the main constraint for optimal production. She would like to have another 10ha, to expand her income base. Farmer #66 makes a lot of money of his sugar. Moreover, he owns several alcohol shops which give him a good second income. He has a lot of money to invest in his sugar. He perceives his main reason for good yields to be good management. He has hired a professional manager, and he checks on his labourers whenever he has free time.

4.2.2.3 Management

As indicated in paragraph 4.2.2.1 11 of the interviewed farmers claim to lack in management skills. The rest of the farmers consider themselves to be good managers, and claim that access to capital is their main constraint. They believe that they are able to manage their sugar adequately, providing they have the money to do so. The 20 farmers who are producing above break-even point, however, claim that sub-optimal farmers' management is lacking. They believe that these farmers lack in commitment, motivation, knowledge, skills and responsibility.

Finances

With good management comes good financial management. The top ten optimal farmes stress the importance of good financial management. They all claim to have a good overview of their cash flows, even though seven of them are illiterate. All of them have hired either an educated family member, or an accountant to help them with making a budget. They stress the importance of paying off debts as quickly as possible, as this reduces total interest, and allows them to build up a buffer for bad years that may follow. They claim to spend their money on maintenance and management of sugarcane first, before spending anything on luxury items. They have been doing this since the beginning, and believe that this sets them apart from sub-optimal farmers who have splurged on luxury items in the successful starting years. It seems that these ten farmers have developed a good network around them, helping them with financial management. They know their exact profits and debts, and try to keep to their budget planning. The other optimal farmers stress that people need to be careful with money. Farmer #59 is producing just above break-even point and is depending on loans. However, as she is afraid of the bank taking all her money, she only farms a small part of her plot. She has calculated the amount of money she can pay back within 4 years, and has adjusted her area of sugarcane according to this amount.

40 of the farmers producing below break-even point consider themselves to be good managers. They stress that their problems are not their faults. Of these 40 farmers 6 admit that they may have made bad decisions in the starting years by neglecting certain farm activities (e.g. ripping the soil) in order to buy a BMW or Mercedes. These 6 farmers indicate that many other farmers also spent money on luxury items in the beginning, instead of using it to invest back into the farms, even though these farmers might be reluctant to admit so. However, driving around in the Lower Komati area, it is clear that there are indeed many expensive cars around. As these farmers made unwise decision in the beginning years, less and less money was spent on maintenance of their plots. Now the yields are dropping, these farmers do not have a buffer income to repair the damage. Akwandze has two loan officers in the field who offer financial advice. They give recommendations and alternatives for taking a loan and how to best spend the money. They also try to monitor the money to make sure it gets used for sugarcane production, and not for household needs (AKW, 2008). These extension workers can help farmers with making a business plan, but farmers need to ask for it, which again depends on farmers' commitment and initiative. Extension can be helpful when it comes to improving farmers' financial management. TSB would like to see production loans in future made dependent on the grower in consultation with an agricultural economist drawing up a business plan to which the grower would have to agree and stick (TSB-3, 2008). Currently, much of the good advice and help cannot be implemented simply because the grower lacks funds. This lack of funds caused farmer #13 to harvest his cane early. His cane was not optimal yet, but he desperately needed the money. He realizes that harvesting cane early will negatively affect the yield and his income, but indicates that some money is better than nothing.

Related to financial management is the fact that social aspects have changed over the years. People have become more demanding and like to have cars, cell phones and nice clothes. The family is an important unit for black farmers, and all indicate that kids, grandkids, brothers and sisters demand a lot from them. The older interviewed farmers are grandparents, who indicate that they do not want to let their grandkids down when these ask for soda or candy.

Soil

Cane can grow on many soil types, but when soils are marginal farmers have to accept that their yields cannot be optimal. This means that for the worst soils, high management and technical competence is essential. Marginal soils can still yield above 100ton/ha for the first three years. Afterwards, yields are likely to stabilize around 90ton/ha (BT-2, 2008). The top 20 interviewed farmers all indicate that they are very hard workers who love farming. It seems that they are by nature achievers and hard workers. They are sharp and have a business attitude. They stress the importance of good management, and twelve of them have hired agricultural professionals to help them with this. Some farmers offer their management skills to other farmers in the form of consultancy work (e.g. farmer #58). Management of land under tribal authorities is a different matter. It turns out that chiefs usually own plots with a very low yield production or no cane at all. The interviewed farmers describe the chiefs as lazy and alcoholic. Chiefs often have not finished school, and inherited the plots from their dads. They receive government money for being a chief, but do not care about managing their sugarcane plots. The interviewed farmes indicate that chiefs expect other farmers to do the work for them, but as this doesn't happen their yields deteriorate.

As described in chapter 3, part of the farmers on marginal soils have been able to improve their yields, while others have failed. Asking the farmers about this, all 71 farmers stress the importance of fertilizers and weed control. The general feeling of the 20 optimal farmers is that the expenditures of required nutrients must not be cut. Failure to supply the nutrients needed for optimal crop growth will result in sharp reductions in yield and thereby profits. However, only eleven of these farmers have a net income above zero. Six of these do apply 100% of the required nutrients, but the other five have reduced their fertilizer applications due to the high costs. They know that their yield will suffer, but see no other options. This indicates that even for successful farmers, the increasing input prices remain a big burden. One even joked that he can “marry 20 wives for that money”. These five farmers are still producing above break-even point and are merely hoping for their yield (and income) to carry them through to the next season. Of the nine optimal farmers with a zero income, six farmers apply 100% of fertilizers. These farmers have taken short-term loans to help pay for these fertilizers. The 12 optimal farmers applying 100% of required fertilizers are very involved with soil sampling. They indicate to take care of not over- or under- applying fertilizers. They do so by making soil samples and sending these to SASRI (in Durban). However, half of these farmers indicate that SASRI takes six weeks to analyze the soil samples. Sometimes they go ahead and apply fertilizers to their own judgement as they cannot wait for SASRI to come back with the results. The other six seem to plan ahead more carefully. However, they do complain about some contractors delaying the process.

Of the 51 sub-optimal farmers, only nine apply 100% of required fertilizers. What is evident is that these are the farmers with the smallest plotsizes. They themselves indicate that their relatively small plotsizes helps them to apply all the required nutrients as their total costs are less than for farmers with larger plotsizes. However, even though they apply the correct amount of fertilizers, it seems like their other management practices are lacking as they are still producing below the break-even point. The other 42 sub-optimal farmers are limited by finances and order fewer fertilizers than needed. These farmers are more likely to use local fertilizer companies for soil sampling and analysis as these are perceived to be cheaper and faster. A drawback mentioned by the extension workers, however, is that these fertilizer companies are not specialized in sugarcane like SASRI is. They may advice to put extra N to allow for growth, but neglect the need of P and K for sucrose development (SASRI-1, 2008). Farmer #12 complains about contractors not doing their jobs. She hired contractors for fertilization, but only found out months later that they neglected certain parts of her plot. She then called them back, but as she already signed all the papers, the contractors are refusing to come back and spray the rest of her plot. Farmer #21 complains that the contractors ripped him off. He thinks they sold him a fake fertilizer, as his sugar is not growing. Just like farmer #12 he cannot do anything about it, as he already signed all the papers and paid for the job. Farmer #9 indicates to order fertilizers, but he doesn’t apply any to his field. He sells the fertilizers to his neighbours as he is in dire need of some cash for the household. Of all 71 farmers, only four use alternative nutrient sources such as cattle and chicken manure. They use this whenever available by spreading it on top of their soil.

Water

As discussed in chapter 3, the range of values for ET_a and biomass among farmers on marginal soil is larger than this range for farmers on the more fertile soils. This means that part of the farmes have found ways to adequately match their irrigation frequency to the type of soil, while others have failed. Of all 71 farmers, only 8 are using the drip system: four optimal farmers and four sub-optimal farmers. The optimal farmers with drip, farmers #55, #58, #70 and #71, perceive it to be their main advantage over the other farmers. They mention the labour and water savings of this system, but stress that the driplines have to be managed carefully. Farmer #23 is also using drip lines, but her lines are blocked and her yields are low. She does not know why her yields are low, but it is clear that she does not know how to take care of her driplines. This indicates that farmers need to know how to manage driplines before they purchase a system. Farmer #30 is happy with his driplines, but his lines are damaged by fire, as he forgot to take them out during burning of the cane. Farmer #34 has bought a second-hand dripsystem from a commercial farmer, and is still learning how to manage it. He is in talks with some optimal farmers who are teaching him. Farmers #62 to #69 are all using sprinklers, however, they are all producing over 100ton/ha. They are happy with their sprinklers, although some are saving money to buy drips. As these farmers are all good producers it seems that they have found ways to adequately match the frequency of their irrigation to the soil type. They have instructed their labourers when and how to move the sprinklers, and try to leave no part of their plot un-irrigated for over three days.

Engineers from TSB and DoA believe that the emerging farmers are over-irrigating (DoA-1, 2008; TSB-4, 2008), especially the farmers using sprinklers. None of the interviewed farmers know their actual irrigation allocation. They all rely on the hours they receive from the IBs and irrigate accordingly. This means that they will sometimes irrigate when it's not needed, e.g. when it has just rained. In addition, this will make the electricity costs unnecessarily higher.All farmers indicate that they want to use what is 'theirs'. None of them wants to leave water in the river, and they are all trying to always irrigate 100%.

Asking the farmers about their crop water requirement, only two farmers (farmer #58 and #70) know exactly the amount of mm they are irrigating. They have hired an expert to help them with the scheduling. The other 69 farmers do not know how much they are irrigating. They just know the amount of hours they pumping and running their irrigation system. They indicate that irrigation scheduling is their own responsibility and that they do not receive any help with that. They have no knowledge about evapotranspiration and crop water requirements and base their scheduling on assumptions. They irrigate as much as they can, whenever they can. When deciding on how much water to apply, they look at the colour of the cane and the leaves, and feel the wetness of the soil.

Most part-time farmers often hire someone to do the irrigation scheduling and management for them, and these workers may not know exactly how to work the system. Farmer #31 is a businessman who has a plot in Walda. He has hired a worker to manage his floppies. This worker irrigates each block for 12 hours instead of the 3 hours that were designed for this system. He has only worked with regular sprinklers before and does not know about the special floppy design. His way of working leads to over-irrigation of one particular block and water stress for all the other blocks, as the irrigation cycle now lasts 12 days instead of 3.

Farmers #1 (Ngogolo) and #2 (Nhlangu East) indicate that farmers in these two projects suffer mainly from pressure related problems. They explain that many farmers have altered their irrigation system by cutting the hoses. The rest of the farmers are suffering due to the drop in water pressure. Pressure related and distribution problems may also stem from (illegal) land expansion. Especially in Ngogolo and Nhlangu East farmers have extended their lands, transforming bush land to sugarcane plots. They have added extra sprinklers to their land, which has resulted in low pressure irrigation. Ngogolo has expanded to 130% of its original size. Similarly, Nhlangu East has expanded to 115% of its original size (TSB-3, 2008). Due to the lower water pressure all over these projects, the water quantity arriving at the plant has diminished. This is turn leads to lower values for ET_a, biomass and yield production. CWP on the other hand may be positively affected by the lower pressure. Farmers #22, #41 and #42 of Mbongozi complain that their pivots are old, and that the pressure is unequally divided along the system. Land close to the centre tends to receive the most water. Besides, they indicate that in times of drought, the pivot takes too long to reach their plot. They have a special problem regarding the theft of electricity cables. When these cables get stolen the pivot comes to a standstill. It can take weeks for these farmers to organize and replace the cables, which also depends on their financial situation. In the end, all eight farmers sharing one pivot system are suffering because of a lack of irrigation.

Crop

As indicated in chapter 3, the yield in ton/ha does not give a full picture of the situation at hand, especially when it comes to yield variety. 45 farmers grow N19, even though they realize that N25 may produce higher yields. When asked about this, they indicate that N19 has a higher sucrose content than N25. Moreover, they claim that N19 needs less fertilizers, and is more resistant to drought. They thus focus on the economic water productivity, as they apply their water where they believe it have the biggest economic benefit. Ten farmers are growing N25. Their yields range from 30ton/ha to 120ton/ha, indicating that they are not all applying correct management practices. Farmer #58 who has 22.9ha of land, is growing four different varieties. He has matched these varieties to his different soil types. He is thus able to find the resources to identify and implement best practices for sugarcane production. He also takes care of using good quality seed cane, and actively controls pests and diseases.

Farmer #46 is on her 13th ratoon, and explains that her debts cause her to keep a longer ratoon than beneficial for the crop. Her yield is deteriorating, but she simply does not have the finances to replant. Farmer #27 grows his own seedcane, as he cannot afford to buy costly certified (virus free) seed cane. He is on his second ratoon but has low yields, indicating that his seedcane might have lacked in quality. As soon as farmers' yields approach the 50ton/ha mark, their only solution for getting production up again becomes the process of replanting the entire plot (SASRI-2, 2008; TSB-1, 2008). This is a costly process, which all depends on the farmers' ability to get access to finances, which means getting more loans, and going deeper into debt. Farmers who cannot raise finances will find themselves forced to abandon their plots.

Contrary to the commercial farmers, none of the emerging farmers practice intercropping. Extension officers of TSB and SASRI understandably focus on sugar only, and do not give advice on growing other crops. DALA extension officers would like to focus more on teaching farmers about intercropping, but claim that they are not allowed to give advice on this matter, as they need to focus on sugarcane. Vegetable production is the task of another department within DoA (DALA-1, 2008). Farmers #58 and #71, however, do see the benefits of intercropping and are trying to learn more about this matter from commercial farmers.

Besides the problems mentioned above, many farmers all over the projects mention the problem of cattle, warthogs and baboons eating their cane. This mostly occurs during summer when grasses are dying. Farmers talk about their fences being cut by cattle farmers to let the animals graze. Interestingly, some of these cattle farmers are sugarcane farmers themselves. The farmers of Langeloop II all perceive smut to be their number one problem. The whole project was affected by this disease, and all cane had to be destroyed. These farmers are now waiting for a new loan from Land Bank. Farmers in Mzinti and Phiva mostly complain about salty patches in their plots on which no cane will grow. Other common mentioned problems are delays in fertilizer orders, lazy labourers not removing all weeds, contractors damaging cane by driving over it, and the occurrence of runaway fires.

4.2.2.4 On- and Off-Farm Family Labour

As profit margins of sugar keep shrinking it seems that farmers need to increase their income base by either expanding their land or looking for extra income. Farmers wanting more than just their basic needs will need to improve their production. To have an acceptable life style they need to work at a larger scale as it is all about economies of scale, getting costs down and expanding the income base (BT-2, 2008; TSB-3, 2008).

Of the 20 optimal farmers, 16 are full-time farmers. They are committed farmers who depend on their sugarcane production to make a living. They are all looking at expanding, and depending on their financial situation they may purchase additional plots. They stress that a farmer must love to farm and that farming is a calling. To be successful, farmers need to be competitive and go into the field. Unlike the sub-optimal farmers, they say, they do not drive by in their car and look out of the window, but they make sure they are on their plots daily and monitor what is going on. They realize that it's in their own interest to battle diseases, as it will lead to a higher cane quality and thus a higher income. They invest in training and monitoring their labourers, and practice a high level of control. They make sure labourers do their jobs when it comes to weed control etc. as it affects the quality of cane, the total yield production and the farmers' income. Not all full-time farmers are optimal farmers however. Of the 51 sub-optimal farmers, 27 are full-time farmers, with 15 of them having working family member(s) bringing additional money into the household. They all perceive the lack of finances to be the reason for their low yields. These farmers have no income except for child support of ZAR210 per month (providing they have young kids). Farmers above 60 years of age mainly live of their pensioner grants (ZAR 940/month).

Of the optimal farmers #66 owns a couple of alcohol shops, and #71 owns a taxi-business. Two other have temporary part-time jobs. Even though these four people are part-time farmers they are producing high yields. They attribute this to their monitoring and supervising skills, although they have all hired managers to manage for them. As they have high paying other jobs are able to invest money into their farms and have more collateral and better access to loans. This allows them to keep productivity high. Of the sub-optimal farmes, 24 are trying to make an extra income. Their main jobs are selling vegetables, bricks, seed cane or ice-blocks. Farmer #28 is a pre-school teacher, farmer #1 a policeman, and farmer #14 is an Eskom electrician. These three farmers indicate that their full-time jobs limit their time to actually work on their land, which they perceive to be the reason for their low yields. They believe that sugar does not contribute enough to their income, and are unhappy with the once-a-year income. But while they have an additional income it limits their time to actually invest in the farm. They are not able to supervise their labourers optimally, as the time they actually spend on the farm is limited. They cannot monitor their labourers which may result in costly mistakes on herbicide applications or crop damage.

Optimal farmers accuse the sub-optimal farmers of being lazy, and compare their own drive to work with the business sense of Indian immigrants. Farmer #58 stated that very clearly with the following example: "Indian shops have a business attitude. African shops open late as people want to sleep in. Then they close for lunch time and tea time. At the end of the day they close early as people go home to watch their favourite TV-show. How are they supposed to make a profit?"

4.2.3 External Factors Influencing the Emerging Farming Typologies

The previous paragraph explored important internal factors of a farming system influencing values of ET_a, biomass, yield production and CWP within the different farming typologies. External factors influencing the farming systems of the emerging farmers influence the diversity in ET_a, biomass, yield production and CWP further. Different from the commercial farmers, emerging farmers seem to rely much more on these external institutions and factors.

4.2.3.1 Plot Size

During the first phase of NIEP, plots started at 10-15ha. However, as more farmers were selected to participate, the size of the plots reduced. Land was limited, and the smaller the farm size, the more the participants. Most plots are now between 5 and 12ha. At the beginning stage of the projects this proved to be enough as people were making a profit (EF, 2008; TSB-3, 2008). People were able to make a living, and emerging farmers even had higher average yields than commercial farmers (TSB-3, 2008) as their small plots needed less inputs (and investments) than the large plots of the commercial farmers. Somehow, they were able to manage their small plots more effectively. These days, due to the cost-pinch, people are currently struggling to make a living. Most emerging farmers are not making a profit, but are merely surviving (TSB-3, 2008). With a soil potential ranging from 90ton/ha to 120 ton/ha (BT-2, 2008; PA, 2008) even small plots should be able to make profit as long as they stay above the break-even point, but debt has become a big issue (CG-2, 2008). Debt limits the farmers' choices for the following season, and if they are not careful they will end up in a downward debt spiral, having to take more and more loans to finance their sugar before being cut off. An effect of these financial problems can be seen all over the projects. Plots have been abandoned by farmers looking for other jobs, or simply just giving up, discouraged by their debts. Nhlangu East and West both have very small plots of 2-3 ha, and around 50% of these plots have been abandoned so far. The Cane Delivery Agreement (CDA) with TSB states that the contract will be terminated after 3 years of low harvest (TSB-3, 2008). Farmers who want to get out of the contract will simply stop farming for three years.

Looking closer at these abandoned plots, it appears that these have a relatively high value for ET_a, but a low value for yield production. This is surprising, as yield production is directly related to biomass production. However, as these plots are no longer in use, the relatively high ET_a and biomass that was estimated for these plots is not based on sugarcane, but rather on weeds and bush land. These abandoned plots belong to farmers who have died, are ill, or have left the area to find a job elsewhere. Other plots belong to farmers who sit at home, as they are too old to work on the field, or farmers who have given up on farming as they were discouraged by the hard work. Most of these farmers have struggled for a while, trying to make a living, before entirely giving up. They are either looking for other jobs, or they sit at home and live of their pensioner grant or child support. Some are leasing out their water rights to at least make some money of their plot. Sometimes lands have been abandoned due to transferring problems. Transferring land from one person to the next (e.g. after death) can be time-consuming. People need to fill in forms, and apply for new grower codes. For farmers who do not know the drills and need help with this as they are, for example, illiterate, this can take a while. Other delays can be due to problems within a family about who is supposed to be taking over. As many emerging farmers do not have a will (as they are afraid to be killed for their money) they usually don't specify where their land should go after death. Chiefs are also known to delay transfers by misusing their powers and charging high amounts of money for the change of ownership.

Due to increasing input costs and the declining profits of sugar, it seems that farms need to become bigger to survive. Farmers themselves see their small plot size as a major constraint for optimal yield production and their financial situation as they cannot build up any buffer income like the commercial farmers with their 200-1000ha plots (BT-1, 2008; EF, 2008; TSB-3, 2008). At this stage, some 90% of the small scale growers are still in action (TSB, 2007), and where plots have been abandoned some have been taken over by family members or other growers, bringing about economies of scale. This was anticipated at the time of planning and development. It was recognized that the farmer selection process was probably not ideal and that some people would just not make it. Therefore, some people giving up was projected, as was the amalgamation of farmers with the successful farmers progressively farming larger and larger parcels of lands (Cartwright, 2008a; TSB-3, 2008). With these larger land units, more net farm profits can be earned due to the economies of scale. Optimal farmers are farming bigger areas, make more money, and have more cash resources. They do not always have to take loans. Some are not even full-time farmers as they have other jobs. For future sugarcane projects it is needed to reassess the size of land allocated to growers. However, the social purpose of cane production must not be overlooked. Cane can be the only source of income for a family which means that around 20-40 is needed. However, a 0.5ha plot could have major significance for an old lady eking out an existence with the cane plot income becoming the difference between survival or not (Cartwright, 2008a).

4.2.3.2 Irrigation

NIEP was mostly an infrastructure project, supplying emerging farmers with irrigation schemes needed for sugarcane production. The irrigation systems of the emerging farmers were designed to be collectively managed. The decisions are collective, the committee has to organize, and farmers have to solve their problems together. Emerging farmers are 'project people' which limits farmers' decisions at field level.

Operation and Maintenance

As indicated in chapter 3, emerging farmers are taking their full water allocations, but not all water arrives on their lands. This water is lost through leaks and breaks, stressing the importance of good maintenance. Many projects are plagued by break-downs of irrigation infrastructure. It is often poorly maintained, and needs upgrades and financial investment. Breaks and leaks affect the whole project as the farmers are all part of one irrigation scheme. In many cases, 10 to 12 farmers share one pump. When a pipeline in Walda recently broke this resulted in no water supply for the entire project (EF, 2008). Farmers irrigating in a scheme need to work together when there is a problem, as it affects all of them. What often happens, however, is that few farmers will feel responsible to fix problems such as leaks in a pipeline, especially when the leak is not in their plot (EF, 2008; SASRI-1, 2008). It can take months for someone to take the initiative, and for the farmers to come together. During that time the leak will have gotten much worse. Having unequal water flows and pressure all over a project will then result in an unequal spread of ET_a, biomass, yield production and CWP.

When it comes to repairing the infrastructure other issues come into view, such as the finances that are needed to repair the leaks and breaks. This financial burden must be carried by all farmers, who do not all have the same financial resources. Sometimes fields have been abandoned which leads to the remaining farmers having to pay extra. This is especially a problem in Mbongozi as it makes the pivots very expensive to maintain for the remaining farmers sharing the same pivot. The break-downs of irrigation infrastructure seem to be related to bad maintenance. Many farmers do not know how to maintain their infrastructure, or they wait for the extension workers to help them with it (DALA-1, 2008; EF, 2008; SASRI-2, 2008). However, when there are 80 farmers in one project, there are bound to be problems in cooperation. Therefore, it is important to have a chairman with good leadership qualities. Mbunu B is such a project with strong leadership qualities. The farmers in this project are committed to farming, and work together to maintain their infrastructure. Many influential old farmers are guiding the others (EF, 2008). Ntunda, on the other hand, has no leadership at all, as the farmers are busy with other jobs, and it is difficult to get the committee together for meetings. Most farmers in Walda are part-time farmers with successful other jobs, and many do their own thing, as they don't believe in the expertise of the extension workers (EF, 2008; TSB-1, 2008). Their Farmers Association (FA) just consists of one person, the chairman, and all farmers are operating individually. As discussed in chapter 3, not all of them know how to work the floppy system, which results in low yields for these farmers. A general ignorance of the technicalities of the irrigation systems is plaguing many of the emerging farmers, although training in these matters is available from extension officers.

As organizing limits farmers' decisions at field level, optimal farmers have made their own changes to be successful. They make sure they operate their own equipment. Some have bought their own pump, do not share it with any other farmers anymore, and make sure to maintain it. They replace stolen goods, manage their own irrigation system, and may install their own drip system. They are responsible for their own production system, and do not work together with farmers who lack in maintenance and management. They thus become the sole decision makers, and no one interferes.

The Restructuring Program

As it is clear that the many flaws of the irrigation systems limit production of the emerging farmers, the government has decided to invest in NIEP again. DALA will provide ZAR126 million over the next five years to upgrade irrigation systems (DALA-2, 2008). For the next two years, TSB has agreed to provide seed capital and fund project management, as well as offering extension and irrigation infrastructure support (TSB-3, 2008). DALA has employed Endecon Engineering Consultants to take care of the designs. As it is generally acknowledged that the plot sizes are too small to make a living, the Restructuring Program is mainly looking at farmers to cooperate to pool their land, water rights and other resources to work under the guidance of an experienced manager. TSB stresses that forming a coop will mean survival for the 10% of farmers with bad soils. Farmers like these can become stakeholders and be carried by the other farmers with good soils. One option can be for farmers to create one big management block and employ an official manager. All farmers can then be shareholders to share in the profits. Another option is for farmers to lease out their farming block to a company to receive rent and dividend incomes (BT-1, 2008).

Not all emerging farmers are positive about the restructuring program. Many are excited about the better prospects to make a living, but others fear that they will loose their land. As they couldn't get land in the 'white' area, this primary land ownership is very dear to them. They accuse TSB of just wanting to compensate for land that was lost due to land claims. What is worse, they say, is that people think they cannot manage. Farmers argue that the difficulties are not their fault. They blame it on the bad designs and huge debts. Farmers just need to overcome these challenges, and then they will be able to manage. They oppose the conceptions that they are bad managers and want to overcome the problems themselves: "No one can take over our land" (EF, 2008).

Even so, it seems like the biggest challenge lies in the debts of the growers. If a solution for these debts cannot be found, it is doubtful if the Restructuring Program will be successful. More grants and subsidies will be needed and it is already challenging to find financiers. Moreover, at least ZAR100 million of extra capital is still needed to finance replanting. Debt remains a hard reality. Land Bank has agreed to give out loans to farmers with up to standard infrastructure and good management, but farmers who cannot get out of debt will eventually have to sell their land to a more successful farmer.

4.2.3.3 Government Aid

After completion of the projects, the Ka Ngwane would fix pump problems and take care of general maintenance. The government was responsible for communication and support structures towards the farmers. In 2000 development cooperation was stopped, and the projects were handed over to the farmers (TSB-3, 2008). Farmers indicate that they hadn’t received training in maintenance until that point in time and that they were not aware of the way in which irrigation infrastructure affects finances and production. They just wish someone would have told them to put the electric motors away, when these were destroyed during the 2000 floods. Flood relief funds arrived nine months later, and many farmers found themselves forced to wait for these funds to come through. It seems that an institutional capacity was not developed. Farmers didn’t know what to do, as the government had always done it for them. As the government took away the support structures and communication, the factor lacking among many emerging factors was their skills (SASRI-1, 2008; TSB-3, 2008).

Due to the lack of awareness among emerging farmers, stakeholders brought in expert knowledge to train and educate farmers in order to prevent further problems. Over time, optimal farmers have developed their own institutional capacity. These farmers are no longer waiting for TSB or the government to help them and they take matters into their own hands. They have gained knowledge and skills and are committed to farming as they feel a sense of ownership for their land. As soon as they took ownership of their problems, their maintenance and management skills improved, resulting in increasing yields. Optimal farmers have thus found a way of making enough money to invest back into the farm, pulling themselves out of trouble. Most optimal farmers do not want to say anything bad about the government, because the government contributed a lot, and provided everything. They believe that the farmers must now do it for themselves with help from extension workers.

Among the sub-optimal farmers skills still seem to be lacking. Stakeholders accuse these farmers of demanding an instant wealth. Optimal farmers accuse the sub-optimal farmers of being lazy “in their working and in their thinking” as they sit back and just wait for grants, not realizing that the government has already invested millions in the whole NIEP (EF, 2008). They believe that these farmers lack any form of commitment or ownership. The sub-optimal farmers themselves indicate that they are trying very hard, but that they cannot do anything without money. These are disappointed in the attitude of the government, as they feel that these people have not visited them enough, not fully understand their problems, and have not come up with any long term solutions. They believe that their problems can be overcome provided the government will talk to them regularly and realize just how difficult it is to become established as a grower. They accept that if a grower cannot survive without permanent subsidies every year he is no good and must go, but this does not mean that assistance particularly in drought years is not essential. As the government is promoting BE, they believe that it is essential for new farmers get help for as long as it takes them to become successful (Cartwright, 2008b; EF, 2008).

4.2.3.4 Extension

Extension work is offered to the emerging farmers by TSB, SASRI and DALA. Although many emerging farmers have experience in subsistence farming, commercial farming is a whole different matter (SASRI-2, 2008). Farmers need advice when it comes to soil, irrigation, climate and general management, and they need to be trained. It has proven necessary to demonstrate, show, remind, and train the farmers in all matters related to farming (PA, 2008; SASRI-1, 2008; TSB-1, 2008).

Extension work is carried out by 6 government officials (DALA), 2 SASRI officials, and 4 TSB officials. Together, these 12 extension workers need to educate, train, and monitor over 1500 farmers. With over 125 farmers per extension officer, it is a challenge for these extension workers to help each farmer individually. Especially when they also need to attend meetings, organize workshops, and write reports. With three different organizations involved (SASRI reports to Durban, DALA reports to Nelspruit, and TSB reports to Malelane) some frictions have surfaced between the extension officers as they do not all have the same mind-set. This results in farmers getting three types of information about the same topic, as each organization might, for example, recommend a different type of cane variety. As they have all been trained differently they can all argue why they are right, but it confuses the farmers.
In order to solve arguments among the extension officers, and to have them all preach the same gospel, TSB and DALA have started a doubling-up of extension workers, sending them out in pairs, with the SASRI officials giving technical support (DoA-2, 2008). This pairing up has resulted in inter-personal problems as there are fights about salaries, age, and gender (DoA-2, 2008; TSB-1, 2008). And as there are now 6 teams instead of 12 individuals, fewer farmers can be visited. An issue with government officials is that they regularly have to attend government training courses. This keeps them away from the fields, and from doing their jobs. The other extension workers then need to cover for them, which they do not have time for. This in turn affects the farmers. Farmers must be able to anticipate when the extension worker will be at their projects, so they can come to the office and ask their questions. A farmer needs to be sure that an extension officer will be at the project e.g. every Monday at 9am. It is a challenge for farmers to get money for transport and get to the project as they often do not live nearby. They cannot afford to go to the project randomly to check whether the extension workers are present, they need to be sure (EF, 2008). Unfortunately there is a lack of reliability from the extension workers' side as farmers do not know when to expect them. And when extension workers are not reliable, one might wonder how reliable their advice is.

The difference between optimal and sub-optimal farmers seems to be related to the way they make use of extension. Optimal farmers have developed good relations with the extension workers. They take initiative, and have the tendency to implement more. They do not wait for extension workers to show up in the projects. As the extension officers are busy, optimal farmers make sure to call them for help. Extension workers will respond to these phone calls, as they are very willing to help committed farmers. One farmer has instructed his labourers to call him every time they spot an extension worker. He then rushes to his field, and makes sure he gets to talk to that person. Good relations with extension workers help optimal farmers in their skills and knowledge. They do not need constant monitoring, are learning, and take and apply the advice that is given to them. This is reflected in their relatively high production values. Although not all extension workers are committed to their work, optimal farmers find a way around this, by either calling a different person or going to TSB themselves to ask for help.

Sub-optimal farmers have a problem reaching extension workers. They take a passive attitude, waiting for extension to just show up. They appear to lack knowledge on basic jobs such as taking soil samples or applying fertilizers. This may indicate a flaw in extension work, as there are not enough extension workers to monitor all the farmers, but it also depends on the farmers' own initiative. Many sub-optimal farmers indicate that they do not know how to reach the extension workers or that they are intimidated by them. They feel that extension workers focus on the 'good' farmers only, and that there is no time left for the 'bad' farmers. Farmers tell of extension workers not keeping their appointments, and not showing up, e.g. they will 'forget' to pick up soil samples which results in delays for farmers when it comes to receiving their fertilizers. They accuse the extension workers of making decisions for them, and having them sign papers without knowing what it's for. This will result in contractors showing up to apply chemicals, when a farmer has just applied fertilizers. Farmers are afraid to speak out, to complain, or to ask for help and just continue with their sometimes inefficient practices (EF, 2008). Even optimal farmers feel that training given to farmers about the maintenance and management of systems is sometimes neglected. Even with TSB's labour free assistance on irrigation system repairs, these repairs are expensive and have been known to take considerable time. Some systems have been out of action for three to four weeks at most crucial growing periods with disastrous results (EF, 2008). Optimal farmers agree that some extension workers are not really doing their jobs. They are neglecting the farmers, and do not go to the fields. Some extension workers simply do not visit some farmers as they feel that these people lack finances and cannot apply the advice anyway. Some extension workers have sugarcane plots themselves, and farmers accuse them of focusing on their own projects only (EF, 2008). Optimal farmers believe that better extension work is needed to help the sub-optimal farmers. They believe that these farmers need people to motivate them, and to teach them about the benefits sugar may bring. Extension workers can play a major role in the Restructuring Program, as farmers need to receive management skills and ownership. However, the current extension work needs to be improved. If not, it is likely that the Restructuring Program will repeat the last 10 years of NIEP.

4.3 Conclusion

The previous chapter made a start with exploring the diversity of ET_a, biomass, yield production and CWP among farmers in the Lower Komati. It was established that crop-physiological factors and socio-economic factors of water quantity influence this diversity to some extent. However, these factors did not completely explain the diversity in ET_a, biomass, yield production and CWP among commercial and emerging farmers. Therefore, the physical characteristics of sugarcane plots as set out in chapter 3 were used to identify different farming typologies with the same physical characteristics. This chapter has set out final reasons for the diversity in ET_a, biomass, yield production and CWP within a single farming typology. This was done according to the concept of the farming system. The commercial farmers perceived the main constraint for optimal production to be bad management, which is related to farmers' attitude and commitment. In addition, the external factor of land security further influenced the diversity in ET_a, biomass, yield production and CWP as the threat of losing their land keeps part of the farmers from performing at their best. For emerging farmers, access to finances turned out to be the main constraint. Emerging farmers are confident about their management skills, but indicate that they cannot do anything without money. NIEP turned out to influence the farming system of the emerging farmers heavily, and they appear to be more reliant on external institutions such as extension work and the government compared to the commercial farmers.

CHAPTER 5: CONCLUSION AND DISCUSSION

5.1 CONCLUSION

This thesis has attempted to bring social and technical components related to actual evapotranspiration (ET_a), biomass, yield production and crop water productivity (CWP) together. Firstly, a pre-assessment was done in the Netherlands to quantify the variation in ET_a, biomass, yield production and CWP in the Lower Komati sub-catchment. This was done using satellite imagery, remote sensing and the SEBAL model. Secondly, this technical pre-assessment was combined with socio-technical research in South Africa. This research included technical yield measurements by TSB Sugar, as well as farmer questionnaires, farmer group discussions, interviews with relevant stakeholders and field visits. The combination of technical pre-assessment and social research was thus used to explore and describe differences between sugarcane plots in the Lower Komati, as well as differences between farmers and farming systems.

This report started with giving a visual overview of the distribution of ET_a, biomass, yield production and CWP of sugarcane plots in the Lower Komati. In order to explain the reasons for this diversity among commercial and emerging farmers, the effects of three crop-physiological factors (climate, clay content of the soil, and crop variety) on these four parameters were assessed. Starting with the non-manageable factors of climate and clay content of the soil, the effect of climate on ET_a, biomass, yield production and CWP appeared to be smaller than the effect of soil. This may be due to the Lower Komati sub-catchment being too small to have distinctively different climatic zones. Clay content, however, did have a significant impact on values of ET_a and biomass as these values decrease as the soil becomes more marginal. This effect was especially clear among the emerging farmers. This indicates that commercial farmers have in general been more successful at adjusting their irrigation frequency (and systems) to the marginal soil types. It was also established that there is a larger range of these values for farmers on the more marginal soils, meaning that part of the farmers on marginal soils have found ways to adjust their irrigation frequency to the soil type, while others have failed. Yield production and CWP were affected in a similar way by soil type. For the emerging farmers, a more marginal soil leads to lower values for yield production and CWP. For commercial farmers, this effect is less, indicating that they have overall been more successful at adjusting their management practices, such as weed control and fertilizer use, to the more marginal soil types. Assessing the effect of the manageable factor of crop variety on yield production, N25 has the potential to yield more ton/ha than N19, especially on the marginal soil types. Commercial farmers, who have large land sizes and different soil types are generally growing more than two varieties according to their soil types. Most emerging farmers only grow one variety. Over 70% of the emerging farmers prefer N19 over N25. These farmers are focusing on the economic water productivity rather than on the crop water productivity. They are attracted by the high sucrose content of N19, and perceive this variety to give them the most income in return for their water use. The exact effect of crop variety on ETa, biomass, yield production and CWP was difficult to establish, as other factors such as management (the application of fertilizers or weed control) or theft of irrigation equipment may also affect yield production.

Besides exploring crop-physiological factors influencing ET_a, biomass, yield production and CWP, water quantity was explored in a socio-economic way to explain the spread in values further. The manageable factors of water allocations and irrigation types proved to have a further effect on ET_a, biomass, yield production and CWP among farmers, especially among emerging farmers. Water allocations proved to have an influence on ET_a and biomass of commercial farmers, with an advantage for farmers on the Komati River. They did not have much influence on yield production however. For the emerging farmers, water allocations showed to influence all four parameters, with an advantage for farmers on the Komati River. This indicates that, even with non-optimal irrigation systems, farmers on the Komati River are able to apply more water to their lands to benefit ET_a, biomass, yield production and CWP due to their larger water allocations. Irrigation type further influences yield production and CWP. For emerging farmers, the drip system yielded the highest values for yield production and CWP overall. Pivot performed better than drag line sprinklers which might be due to its larger drop size and less evaporation and wind displacement. For the commercial farmers pivot irrigation turned out to be the worst performing irrigation system for yield production. Differences between drips and sprinklers were small, especially on the more marginal soils. Overall, the three main irrigation types had similar values for biomass, while yield production varied greatly. This is an issue that could not be explained in this thesis, and more in-depth research is recommended. Other socio-economic factors related to water quantity, such as design and theft were discussed qualitatively as these factors are likely to influence the variation in ET_a, biomass, yield production and CWP further. Design is especially an issue for the emerging farmers. Each scheme has its own design, with extra design difficulties for the 'seven projects'. All schemes are operated collectively, and farmers generally have to work together when it comes to operation and maintenance and irrigation scheduling.

After exploring the effect of crop-physiological aspects and the socio-economic effects of water quantity on values for ET_a, biomass, yield production and CWP of farmers, this diversity had still not fully been explained. In chapter 4, different farming typologies were established based on the physical characteristics of the sugarcane plots and the type of farmer. It turned out that plots with similar characteristics (e.g. same type of farmer, same soil, same water allocation, same irrigation type and same design) still had different production values. Final explanations for this diversity had thus to be sought within the farming typologies of the farmers. The different typologies were based on the two main farming systems in the area, and set standards for farmers to improve their water, fertilizer and crop management, in other words: manageable factors. These include the socio-economic aspect of soil fertility (fertilizers), as well as aspects related to crop management, skills, labour, commitment and finances.

It turned out that each farming typology consists of 'optimal' and 'sub-optimal' farmers. All farmers perceived their main indicator of being either optimal or sub-optimal to be their level of yield production. The commercial farmers perceived their main constraint for optimal yield production to be bad management, which includes management of finances, crop, water and soil. The high rise of input costs is another major constraint for commercial farmers as it limits their ability to buy fertilizers and other inputs. In addition, commercial farmers perceived the external factors of land security and land claims to influence their yield production, as the threat of losing land keeps part of the farmers from performing at their best. Optimal factors for yield production were perceived to be good financial management, good maintenance of the irrigation systems, and the ability to buy fertilizers. For emerging farmers, access to finances turned out to be the main constraint. Emerging farmers are confident about their management skills, but indicate that they cannot do anything without money. They perceive their favourable factors for optimal production to be access to loans, good relations with extension workers, and a commitment to work hard.

This thesis gave an insight in to the characteristics of both commercial and emerging farming systems. The farming system of the commercial farmers is characterised by a modern capital-intensive sugarcane production system with high levels of management inputs. These farmers are contracted to TSB by way of a long-term specification contract and supply around 60% of the total volume of sugarcane delivered to the two mills (TSB, 2007). These farmers are on average highly educated, and most of them operate farms that are in excess of 100ha. In many cases sugarcane is one of the farm enterprises together with sub-tropical fruit and vegetables. They grow a variety of crops, export the crops or sell them to the local market. Commercial farms are managed independently at field level. Many farmers have reservoirs, and they use a broad range of irrigation equipment for their variety of crops. Due to their large land sizes, commercial farmers are able to receive a monthly income from sugar, as they harvest part of their land each month. Most commercial family farms are full-time farmers depending on their farm for livelihood. However, sugar is not always the crop they depend on. In times of water scarcity or financial constraints they may decide to focus on other crops as these may give them better returns on investment.

For emerging farmers, sugarcane production started with the Nkomazi Irrigation Expansion Programme (NIEP). As the NIEP schemes are relatively young, the farming system of the emerging farmers is characterised by a relative inexperience in the day to day operations of high input farming. The average farm size of these growers is 6.8ha, but many have a little vegetable plot for home consumption. Like the commercial farmers, these farmers are also contracted to TSB by way of a long-term specification contract. They supply around 22% of the total volume of sugarcane delivered to the two mills (TSB, 2007). Emerging farmers are part of an irrigation scheme, which limits the choices at field level and requires forms of organization. In all the irrigation schemes, farmers are organized into a farmers' association, charged with all farming-related aspects of the scheme. The emerging farmers are often uneducated and illiterate. Many are plagued by poverty. As emerging farmers only harvest once a year, they receive an income from sugar just once a year. NIEP turned out to influence the farming system of the emerging farmers heavily, as these farmers appear to be more reliant on external institutions, such as extension and the government, compared to the commercial farmers. The technological package that NIEP offered the emerging farmers has influenced their farming systems greatly. The government created the environment, and provided the initial care and exit strategy, and the livelihood of emerging farmers depends on a successful outcome of the NIEP.

Even though some 'optimal' emerging growers compete with commercial farmers in terms of ET_a, biomass and yield production, their farming system still differs from the commercial farming system. Obvious differences between the two farming systems can be found internally, within the household. Commercial farmers have a more 'Western' farming system, with parents taking care of their kids until the kids have finished college and can take care of their own. Commercial farmers have all finished high-school, and many have gone to an agricultural college or university. In emerging farming systems the mother is often the core, as many men have gone elsewhere for work. Women are predominantly responsible for family and food security. Grandparents often live with the family, and family away makes contributions to the family income. Most emerging farmers have not finished high-school, and many have had no education at all. Their lifestyle and education centres around the tribal authorities (the chief). Successful emerging farmers are mostly committed full-time farmers depending on their crop for a living. Other emerging farmers have realized that they need an extra income to supply for the household and have resorted to off-farm jobs.

Production financing still differs hugely between emerging farmers and commercial farmers. Besides having a higher net income due to their huge land holdings, commercial farmers also have more money for savings. They may have a mortgage on their property, but have enough cash/savings to cover the annual production costs. They are able to make payments relatively easily and quickly. Farmers who are in financial trouble may sell a capital item, e.g. a tractor to get some extra cash. Very few emerging farmers have cash resources for immediate work. Most will work from the retention fund, and many are troubled by delays when applying for loans. Even optimal emerging farmers cannot order fertilizers far ahead, like the commercial farmers can. They order it whenever they need it, and when transport takes longer than expected it may affect their yield production.

Another difference concerns the use of contractors. Emerging farmers are very much reliant on contractors. A lot of the work, e.g. fertilizer application, weed control, ploughing, harvesting, loading, transporting, is done by contractors. Commercial farmers mostly do their own jobs as they own tractors and vehicles, and they do not have to wait for other people to do it for them. However, owning tractors and equipment means that commercial farmers will end up spending a lot of time of maintenance instead of management. They also need to take care that their machinery is utilized effectively to limit costs. Some commercial farmers may be better off using contractors, like the emerging farmers, as it can result in savings on personnel, security and maintenance.

Land size also still differs between emerging farmers and commercial farmers. Although some emerging farmers have bought extra plots and the successful ones farm plots around 30ha, this does not compare to the land size of the commercial farmers who farm at least 100ha. Many successful emerging farmers want to expand and make the move to commercial farming, but financial constraints make access to land a problem. Besides having more land, commercial farmers also grow different types of crops. They diversify and search for their own market. As farming is a gamble, they farm sugar for security, and grow cash crops for extra money and try to hit the different markets at the right times. Emerging farmers rely solely on sugarcane, and have trouble finding markets for other crops. They do not have enough knowledge about markets, and do not know when to send their crops to the market and when not. The fact that TSB is offering a ready and stable market for sugar keeps them from producing other crops. They do often grow some vegetables for home consumption and try to sell the surplus along the road. While some commercial farmers may use their machinery ineffectively, some emerging farmers are using their labour ineffectively. Even full-time emerging farmers with 2.5ha plots are known to hire at least one person to shift the sprinklers. Many also employ a person for weed control. Commercial farmers are decreasing their labour force and may employ only one labourer per 10-15ha.

Even though some emerging farming systems have ‘commercialized’ somewhat, there are clearly still huge differences with the commercial farming systems. In this way, NIEP has not contributed to a rural transformation from emerging farming systems to commercial farming systems. When looking solely at values for ET_a, biomass, yield production and CWP, however, it can be concluded that some emerging farmers have indeed transformed to commercial producers, as they are operating at similar levels. Others have failed, as these farmers have low levels for ET_a, biomass, and yield production. However, it must be stressed again that both emerging and commercial farmers have optimal and sub-optimal farmers. Not all commercial farmers are really operating at commercial levels, as they may have low values for ET_a, biomass, yield production and CWP due to financial constraints or land insecurity. Fields with high ET_a, biomass, yield, and CWP are thus not necessarily related to farmers with a commercial farming system. High and low values for ET_a, biomass, yield, and CWP can be found among both commercial and emerging farmers.

When it comes to the three main NIEP objectives of poverty reduction, skill enhancement and diversification, NIEP has indeed brought some improvements to the area. Due to NIEP there has been a big improvement in home building, vehicles, and the general standard of living throughout the area, indications of increased prosperity. NIEP bought electricity and running water to the area, but also better education prospects and job opportunities. Irrigation has spread some wealth, but at the same time, many farmers moved in the opposite direction, as they got themselves into more and debt, and are sometimes even poorer than they were before NIEP. When it comes to the skills of the farmers, the optimal farmers seem to have acquired sufficient skills for sugarcane production, while sub-optimal are still lacking in this department. This can be due to flaws in extension work, but also depends on farmers' commitment and initiative. Skills for diversification were never taught to the farmers. Understandably extension workers of TSB and SASRI focused on sugar only. Even so, most emerging farmers are happy with their sugar plot due to the guaranteed market. They find it difficult to find markets for other crops, and stick with what they have. Almost all emerging farmers heavily depend on TSB and keep renewing their contract with the mill. The struggling farmers say it is better than nothing, and are hoping for better times. These farmers mostly live of child support and pensioner grants. Others have resorted to off-farm jobs to supplement their income.

5.2 DISCUSSION

Similar to the research by WaterWatch (Soppe *et al.*, 2006) this thesis has related technical pre-assessment of satellite imagery and remote sensing to socio-technical research in the field. The WaterWatch research, however, focused on differences between pixels, while this research focused on differences between plots. As sugarcane plots were the focus of interest, this research became much more personal than the research by WaterWatch. Farmers related to the images that were shown to them and were able to identify their own plot. Looking at maps of, in particular yield production, farmers were able to see relative yield differences between themselves and the farmers around them. This made it easy to focus on the farmers' perspective with the remote sensing images as a guideline. None of the farmers questioned the results of SEBAL, and showing them the images made it very easy to start a conversation.

When it comes to the diversity in ET_a, biomass, yield production and CWP among farmers, the results in this thesis are similar to the results of WaterWatch. However, due to the simplified SEBAL approach that was used in this research, only relative differences in ET_a, biomass, yield production and CWP could be portrayed. A limitation concerned the lack of recent satellite imagery. SEBAL may be a great tool for predicting crop yields, and for calculating ET_a, biomass and CWP, but care needs to be taken that suitable amounts of satellite images are used for analysis. This research showed that a limited amount of images may easily result in over-estimations of ET_a and biomass. However, for the purpose of comparing optimal to sub-optimal farmers, relative differences in ET_a, biomass, yield production and CWP among farmers proved to be enough. As satellite images are nowadays easily available, the same method as was used in this research can be easily applied to other irrigation schemes in the world. However, as mentioned before, a distinction might have to be made between absolute and relative differences. Moreover, it is recommended to do in-depth case-studies of specific farmers e.g. of optimal emerging farmers and sub-optimal emerging farmers in order to get insights into ‘how’ and ‘why’ questions of farmers related to their management choices.

This thesis has highlighted measures for future policy. The Restructuring Program, for example, has recently been started to lift sub-optimal emerging farmers to the level of optimal emerging farmers. However, it is clear that many challenges remain. The biggest challenge seems to be in the debt of the farmers. A solution for these debts needs to be found for the restructuring program to be successful. As the aim of the restructuring program is to establish management units, it may be questioned whether hiring a manager will help farmers really emerge. Care must be taken that the goals of Black Empowerment (BE) are adequately reached, i.e. that emerging farmers must participate in their community and develop skills. It is essential that management skills are transferred to the farmers adequately. Extension can help in this aspect, but the extension work that is currently in place needs to be improved as chapter 4 has showed that this is still lacking in many aspects. It is clear that the restructuring program comes with many challenges.

5.3 RECOMMENDATIONS

In the end, this thesis has helped in providing a better understanding of the types of methods that can be used for exploring differences between farmers and their farming systems. Even though the use of standard questionnaires may have limited the actor perspective somewhat, a general view could be given of the optimal factors and constraints as perceived by these farmers. For further research it is recommended to do in-depth case-studies of specific farmers e.g. of optimal emerging farmers and sub-optimal emerging farmers. People of TSB and DoA still tend to attribute the problems of the emerging farmers to their bad management skills. However, NIEP was merely an infrastructure program and not a management project. These new farmers did have a worse starting position compared to the commercial farmers. Their soils are more marginal, they did not have a background in farming, some of their designs were inadequate, they do not have storage dams, and they ended up with huge loans and debts. Doing extensive case-studies may give more insight into these specific constraints for emerging farmers that were forced upon them by the NIEP. It will show that management is more complex than the government and TSB believe. It will also set out different ways of farmers in handling these constraints, which have led some of them to become successful while others have failed. In summary, in-depth case-studies will give more insight into ‘how’ and ‘why’ questions in relation to farmers’ management decisions.

Another recommendation for further research concerns the Restructuring Program. As this program is just starting, it would be interesting to assess this program five years from now. In 2014, another research can be done to compare the different farming systems in the Lower Komati, as well as their values for ET_a, biomass, yield production and CWP. A new assessment can be made with up-to-date satellite images in order to get an overview of changes of these four parameters over time. In addition, the socio-economic objectives of the NIEP should be assessed once again, as well as the BE objectives, in order to explore the initial transition objectives of NIEP. It would be interesting to study the way the restructuring program has affected the land reform process.

REFERENCES

Anderson, A. (2001). *The Plough and the Gun. Part I: An Evaluation of the Nkomazi Irrigation Expansion Programme in the Mpumalanga Province of South Africa*. Plan 572: The theory and practice of project planning in the third world.

Armitage, R. (2008). *Setting the Scene – Grower Cost Trends and Outlook.* SASRI and CANEGROWERS Grower Day: Controlling Costs – 'Managing the Pinch'. August 21, 2008. Malelane, South Africa.

Bastiaanssen, W.G.M. & Ali, S (2002). A new crop yield forecasting model based on satellite measurements applied across the Indus Basin, Pakistan. *Agriculture, Ecosystems and Environment* 94: 321-340.

Beets, W.C. (1990). *Raising and Sustaining Productivity of Smallholder Farming Systems in the Tropics*. AgBé Publishing. Alkmaar, the Netherlands.

Ben-Gal, A., Karlberg, L., Jansson, P.E. & Shani, U. (2003). Temporal Robustness of Linear Relationships between Production and Transpiration. *Plant and Soil*. 251: 211-218.

Bernstein, A. & McCarthy, J. (2008). *Land Reform in South Africa. Getting Back on Track.* CDE Research No 16. Centre for Development and Enterprise. Johannesburg, South Africa.

Bos, M.G., Burton, M.A. and Molden D.J., (2005). *Irrigation and drainage performance assessment, Practical Guidelines*. Wallingford. Oxfordshire, UK.

Brown, J. (2008). *Participatory approaches to Integrated Catchment Management in South Africa*. Chapter of unfinished PhD. Dissertation, University of Manchester.

Brown, J. & Woodhouse, P. (2004). *Pioneering Redistributive Regulatory Reform. A Study of implementation of a Catchment Management Agency for the Inkomati Water Management Area, South Africa.* Working Paper Series. Centre of Regulation and Competition, University of Manchester, Manchester, UK.

CANEGROWERS (2008). Who we are, what we do. Retrieved December 3, 2008, from http://www.sacanegrowers.co.za/AllAboutUs/WhoweareWhatwedo/tabid/57/Default.aspx.

Carmo Vaz, A. & Van Der Zaag, P. (2002). *Sharing the Incomati Waters: Cooperation and Competition in the Balance*. UNESCO. Paris, France.

Cartwright, T. (2008a). *Nkomazi Irrigation Expansion Scheme – Road Map Article*. Unpublished document.

Cartwright, T. (2008b*). Interview With Two Farmers*. Unpublished document.

Church, A.D. (2008). *Rent Options: An Historical Overview*. In: The Cane Grower. Volume 15, Number 5.

DALA. (2005). *Integrated Resource Information Report Nkomazi*. Mpumalanga Provincial Government. Mpumalanga, South Africa.

Department of Environment and Tourism (2008). *Maps & Mapping*. Retrieved January 30, 2009, from http://www.environment.gov.za/.

De Wit, C.T. (1958). *Transpiration and Crop Yields*. Institute of Biological and Chemical Research on Field Crops and Herbage. Wageningen, The Netherlands.

Dixon, J., Gulliver, A. & Gibbon, D. (2001). *Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World*. FAO and WorldBank. Rome, Italy, and Washington D.C., USA.

DWAF (2000). *Inkomati Water Management Area. Overview of Water Resources Availability and Utilisation*. Pretoria, South Africa.

DWAF. (2004). *Inkomati Water Management Area: Internal Strategic Perspective*. Pretoria, South Africa.

DWAF/DFID. (2004). *Guide to Determine the Lawfulness of Existing Water Uses*. Pretoria, South Africa.

Eaton, C. & Shepherd, A.W. (2001*). Contract Farming. Partnerships for Growth*. FAO Agricultural Services Bulletin 145. FAO, Rome, Italy.

FAO. (1998). Crop Evapotranspiration (guidelines for computing crop water requirements). *Irrigation and Drainage Paper No. 56*. FAO, Rome, Italy.

FAO Statistics Division, FAOSTAT (2008). *Major Food and Agricultural Commodities and Producers*. Retrieved July 4, 2008, from http://www.fao.org/es/ess/top/commodity.html?lang=en&item=156&year=2005.

Faysse, N. & Gumbo, J. (2004) *The transformation of Irrigation Boards into Water User Associations in South Africa: Case Studies of the Umlaas, Komati, Lomati and Hereford Irrigation Boards*. Working Paper 73, Volume 2, IWMI,

Floppy Sprinkler (2008). Retrieved February 4, 2009, from http://www.floppysprinkler.com/component/option,com_wrapper/Itemid,49/.

Hanks, R.J. (1974). Model for Predicting Plant Yield as Influenced by Water Use. *Agronomy*. J. 66: 660-665.

Kirsten, J. & Sartorius, K. (2002). *Farm Agribusiness Linkages in South Africa: Empowering Disadvantaged Communities Through Links with Agribusiness*. Working Paper 2002-11. Department of Agricultural Economics, Extenstion and Rural Development. University of Pretoria, Pretoria, South Africa.

KOBWA. (2007). *Komati Basin Water Authority Annual Report 2006/2007*. Driekoppies, South Africa.

KOBWA. (2008). KOBWA: Komati Basin Water Authority. Retrieved December 4, 2008, from http://www.kobwa.co.za/.

Lyne, P. (2008). *Controlling Machinery Costs – Improving Profitability*. SASRI and CANEGROWERS Grower Day: Controlling Costs – 'Managing the Pinch'. August 21, 2008. Malelane, South Africa.

MBB. (1997). *A Great African Success Story. Nkomazi Special Edition*. FOKUS. Newsletter of MBB Consulting Engineers Incorporated. September, 1997. Nelspruit, South Africa

MBB, ACER and AWARD. (2000). *Proposal for the Establishment of a Catchment Management Agency for the Inkomati Basin*. Department of Water Affairs and Forestry.

Murray, J. (2008). *Managing Farm Debt and Overheads*. SASRI and CANEGROWERS Grower Day: Controlling Costs – 'Managing the Pinch'. August 21, 2008. Malelane, South Africa.

Murray, T.J. (2008). *The Chairman's Speech*. In: Mpumalanga Cane Growers Association Newsletter. Volume 3, Issue 2.

Nkomazi Local Municipality (2007). *Integrated Development Plan 2006/2007*. South Africa.

NOWAC. (1999). *The Contribution of Irrigation to the Nkomazi/Onderberg region of Mpumalanga*. Nkomazi/Onderberg Water Action Committee. Malelane, South Africa.

ProdSTAT Crops, FAOSTAT. (2008). Retrieved July 4, 2008, from http://faostat.fao.org/site/567/ DesktopDefault.aspx? PageID=567.

Rhodes, R. (2008). *Managing the Cost of Sugarcane Nutrition – Targeting Nutrition Efficiencies*. SASRI and CANEGROWERS Grower Day: Controlling Costs – 'Managing the Pinch'. August 21, 2008. Malelane, South Africa.

Sartorius, K. (2003). *Linking Small-Scale Farmers to Agribusiness: The Economics of Contracting*. Doctoral Thesis. Faculty of Economic and Management Sciences, University of Pretoria, Pretoria, South Africa.

SASA (2008a). *South African Sugar Industry Directory 2008/2009*. Durban, South Africa.

SASA. (2008b). Homepage. Retrieved December 3, 2008, from http://www.sasa.org.za/HomePage1.aspx

SASRI. (2008a). *Recent Weather Data*. Retrieved December 3, 2008, from http://sasex.sasa.org.za/irricane/tables/.

SASRI. (2008b). SASRI Info Pack CD-ROM 2008. Durban, South Africa.

SASRI. (2008c). Overview of SASRI. Retrieved December 3, 2008, from http://www.sasa.org.za/OverviewofSASRI196.aspx.

Schoch, D. (2007). *South Africa's Water Reserve: Obstacles and Opportunities. A case study of the Basic Human Needs Reserve and basic water services in southern Nsikazi and the Ecological Reserve in the Crocodile sub-catchment, South Africa*. MSc. Thesis. Irrigation and Water Engineering Group. Wageningen University, the Netherlands.

Shani, U. & Hanks, R.J. (1993). Model of integrated effects of boron, inert salt, and water flow on crop yield. *Agronomy*. J. 85: 713-717.

Soppe, R., Hellegers, P., Perry, C., Boon, D., Bastiaanssen, W., Wit, M. de & Pelgrum, H. (2006). *Combining Remote Sensing and Economic Analysis to Assess Water Productivity. A demonstration project in the Inkomati Basin*. Final Report. Wageningen, The Netherlands.

The South African Labour Guide. Your Guide to Labour Law in South Africa (2009). *Sectoral Determination 13: Farm Workers.* Retrieved January 15, 2009, from http://www.labourguide.co.za/farm_section.htm.

TSB. (2004). *Komati and Malelane Yield Data 2003/2004*. Malelane, South Africa.

TSB. (2005). *Komati and Malelane Yield Data 2004/2005*. Malelane, South Africa.

TSB. (2006). *Komati and Malelane Yield Data 2005/2006*. Malelane, South Africa.

TSB. (2007). *Komati and Malelane Yield Data 2006/2007*. Malelane, South Africa.

Van Der Merwe, A. (2008). *Cane Supply Department Extension Service*. PowerPoint presentation 11-4-2008. TSB. Malelane, South Africa.

Van Der Merwe, J. (2008). *Irrigation – Controlling Cost through Better Water Management.* SASRI and CANEGROWERS Grower Day: Controlling Costs – 'Managing the Pinch'. August 21, 2008. Malelane, South Africa.

Waalewijn, P. (2002). *Squeezing the Cow. Perceptions and Strategies of stakeholders, concerning river basin management in the Lower Komati River, South Africa*. MSc. Thesis. Irrigation and Water Engineering Group. Wageningen University, the Netherlands.

Waalewijn, P., Wester, P. & Straaten, K. van. (2005). Transforming River Basin Management in South Africa. Lessons from the Lower Komati River. *Water International*, volume 30, number 2, pages: 184-196.

Woodhouse, P. (2008). *Water Rights in South Africa: Insights from Legislative Reform*. BWPI Working Paper 36. Institute for Development Policy and Management, School of Environment and Development, University of Manchester, Manchester, UK .

Woodhouse, P. & Hassan, R. (1999). *Implementation of the National Water Act: Catchment Management Agencies: Interests, Access and Efficiency*. Inkomati Basin Pilot Study. DWAF, South Africa.

ANNEXES

Annex I: Projects of Emerging Farmers in the Lower Komati

Annex II – A: Evapotranspiration of Sugar Fields for Commercial Farmers 2004/2005
Annex II – B: Biomass Production of Sugar for Commercial Farmers 2004/2005
Annex II – C: Sugar Yield for Commercial Farmers 2004/2005
Annex II – D: Crop Water Productivity of Sugar for Commercial Farmers 2004/2005
Annex II – E: Evapotranspiration of Sugar Fields for Emerging Farmers 2004/2005
Annex II – F: Biomass Production of Sugar for Emerging Farmers 2004/2005
Annex II – G: Sugar Yield for Emerging Farmers 2004/2005
Annex II – H: Crop Water Productivity of Sugar for Emerging Farmers 2004/2005

Annex III – A: Histograms showing the influence of climate and soil on ET_a, biomass, yield production and CWP
Annex III – B: Histograms showing the influence of crop variety on ET_a, biomass, yield production and CWP
Annex III – C: Histograms showing the influence of water allocations on ET_a, biomass, yield production and CWP
Annex III – D: Histograms showing the influence of irrigation type on ET_a, biomass, yield production and CWP

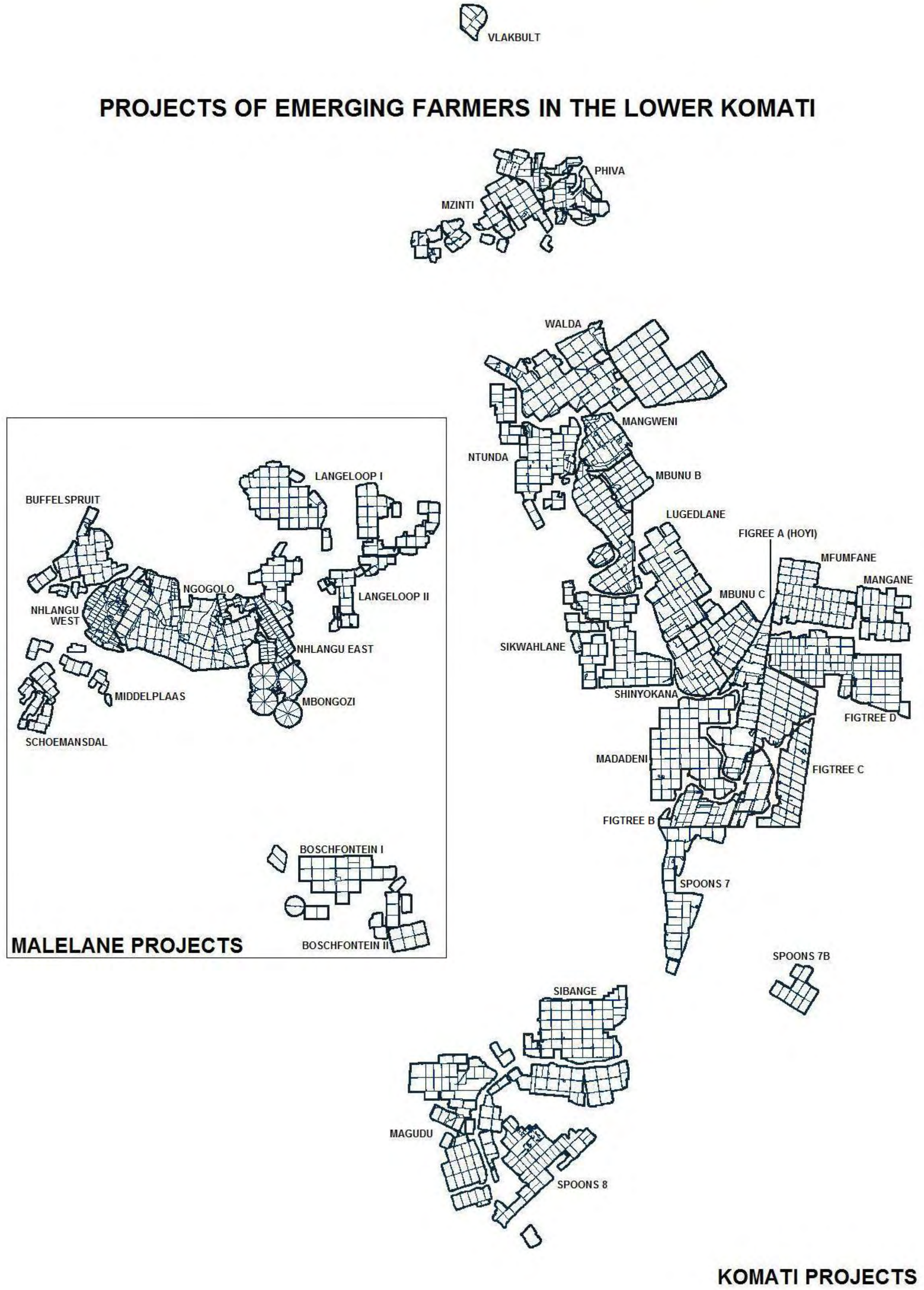
LEGEND ANNEX IV AND V

Annex IV - A: Overview of farming typologies for commercial farmers on the Komati River and the diversity in ET_a
Annex IV - B: Overview of farming typologies for commercial farmers on the Komati River and the diversity in biomass
Annex IV - C: Overview of farming typologies for commercial farmers on the Komati River and the diversity in CWP
Annex IV - D: Overview of farming typologies for commercial farmers on the Lomati River and the diversity in ET_a
Annex IV - E: Overview of farming typologies for commercial farmers on the Lomati River and the diversity in biomass
Annex IV - F: Overview of farming typologies for commercial farmers on the Lomati River and the diversity in CWP

Annex V - A: Overview of farming typologies for emerging farmers on the Komati River and the diversity in ET_a
Annex V - B: Overview of farming typologies for emerging farmers on the Komati River and the diversity in biomass
Annex V - C: Overview of farming typologies for emerging farmers on the Komati River and the diversity in CWP
Annex V - D: Overview of farming typologies for emerging farmers on the Lomati River and the diversity in ET_a
Annex V - E: Overview of farming typologies for emerging farmers on the Lomati River and the diversity in biomass
Annex V - F: Overview of farming typologies for emerging farmers on the Lomati River and the diversity in CWP

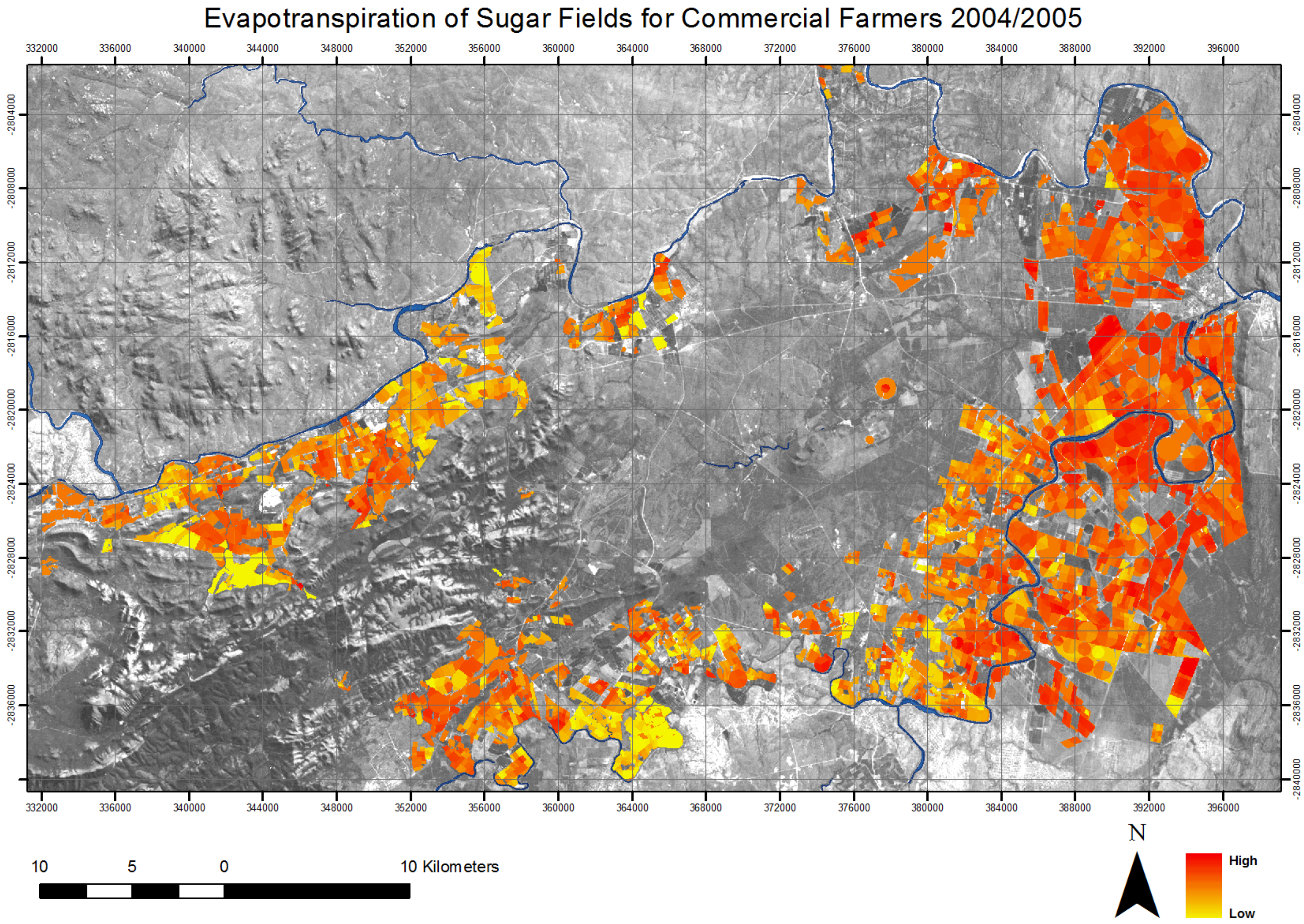
Annex VI: Technical Annex

Annex I



VLAKBULT
PROJECTS OF EMERGING FARMERS IN THE LOWER KOMATI
PHIVA
MZINTI
WALDA
MANGWENI
NTUNDA
MBUNU B
LUGEDLANE
FIGREE A (HOYI)
MFUMFANE
MANGANE
MBUNU C
SIKWAHLANE
SHINYOKANA
FIGTREE D
MADADENI
FIGTREE C
FIGTREE B
SPOONS 7
SPOONS 7B
SIBANGE
MAGUDU
SPOONS 8
KOMATI PROJECTS
LANGELOOP I
BUFFELSPRUIT
NGOGOLO
LANGELOOP II
NHLANGU WEST
NHLANGU EAST
MIDDELPLAAS
MBONGOZI
SCHOEMANSDAL
BOSCHFONTEIN I
BOSCHFONTEIN II
MALELANE PROJECTS

Annex II - A



Evapotranspiration of Sugar Fields for Commercial Farmers 2004/2005
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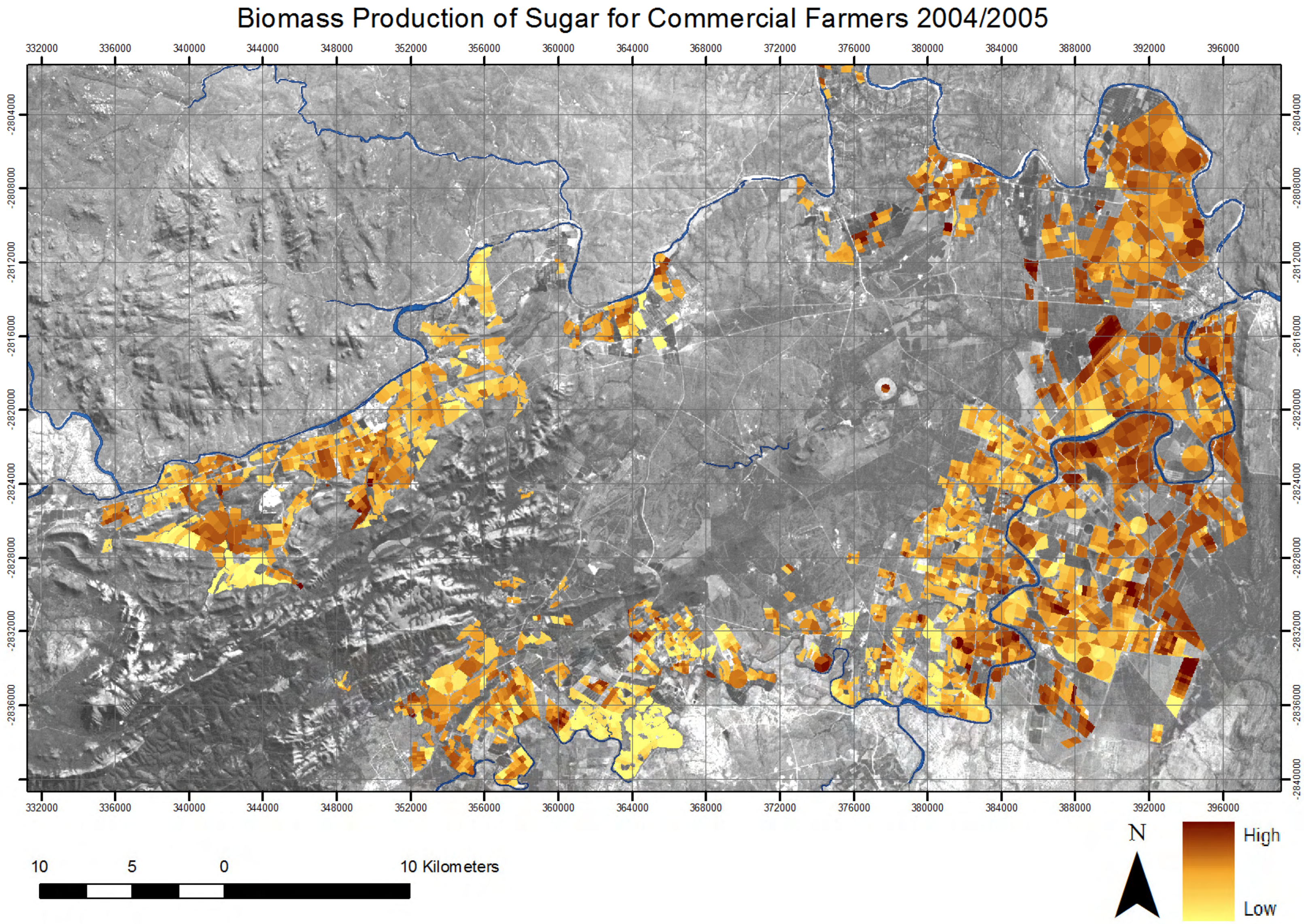
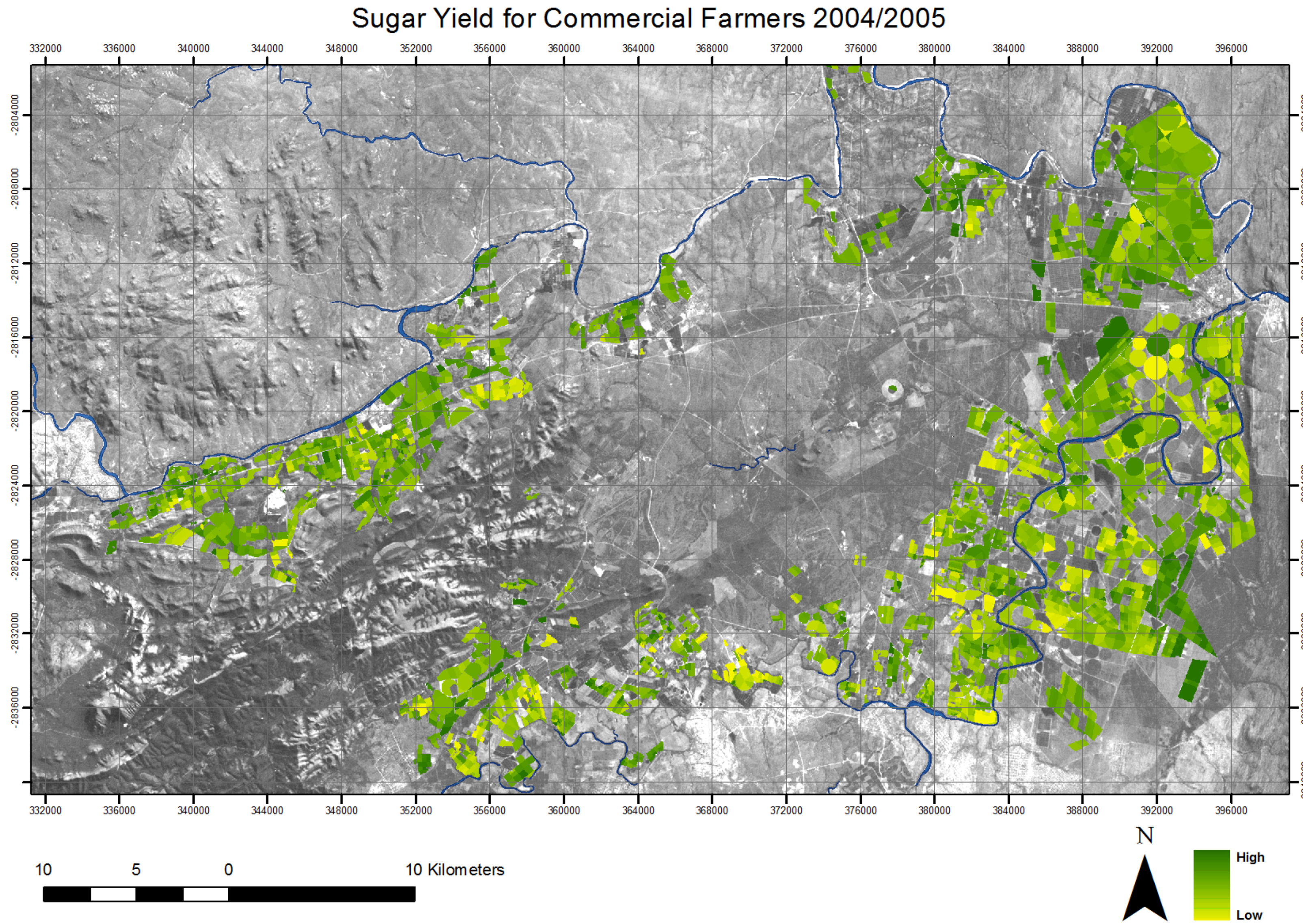
Low

Annex II - B


Biomass Production of Sugar for Commercial Farmers 2004/2005
332000
336000
340000
344000
348000
352000
356000
360000
364000
368000
372000
376000
380000
384000
388000
392000
396000
-2804000
-2808000
-2812000
-2816000
-2820000
-2824000
-2828000
-2832000
-2836000
-2840000
10
5
0
10 Kilometers
N
High
Low

Annex II - C



Sugar Yield for Commercial Farmers 2004/2005
332000
336000
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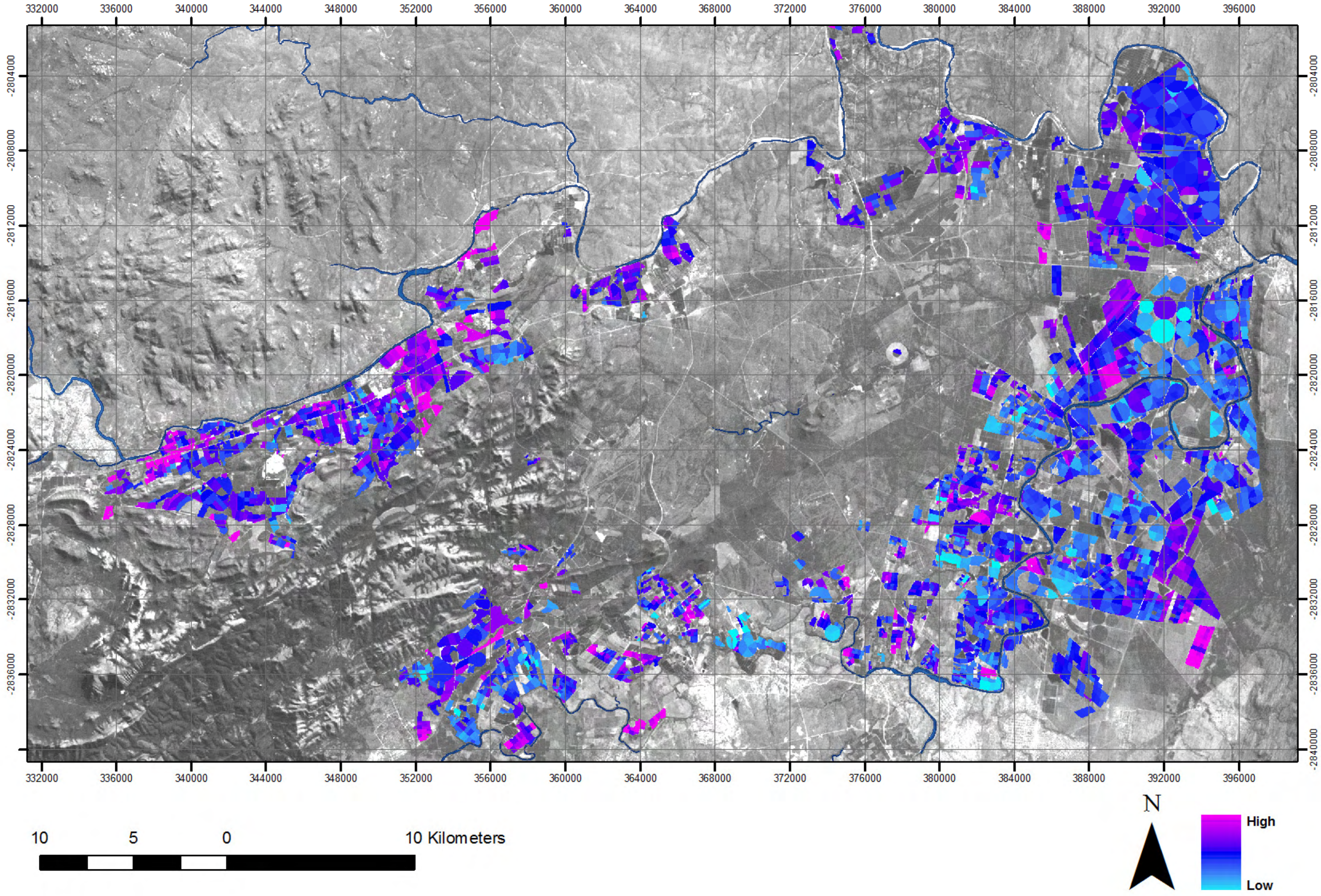
344000
348000
352000
356000
360000
364000
368000
372000
376000
380000
384000
388000
392000
396000
-2804000
-2808000
-2812000
-2816000
-2820000
-2824000
-2828000
-2832000
-2836000
-2840000
10
5
0
10 Kilometers
N
High
Low

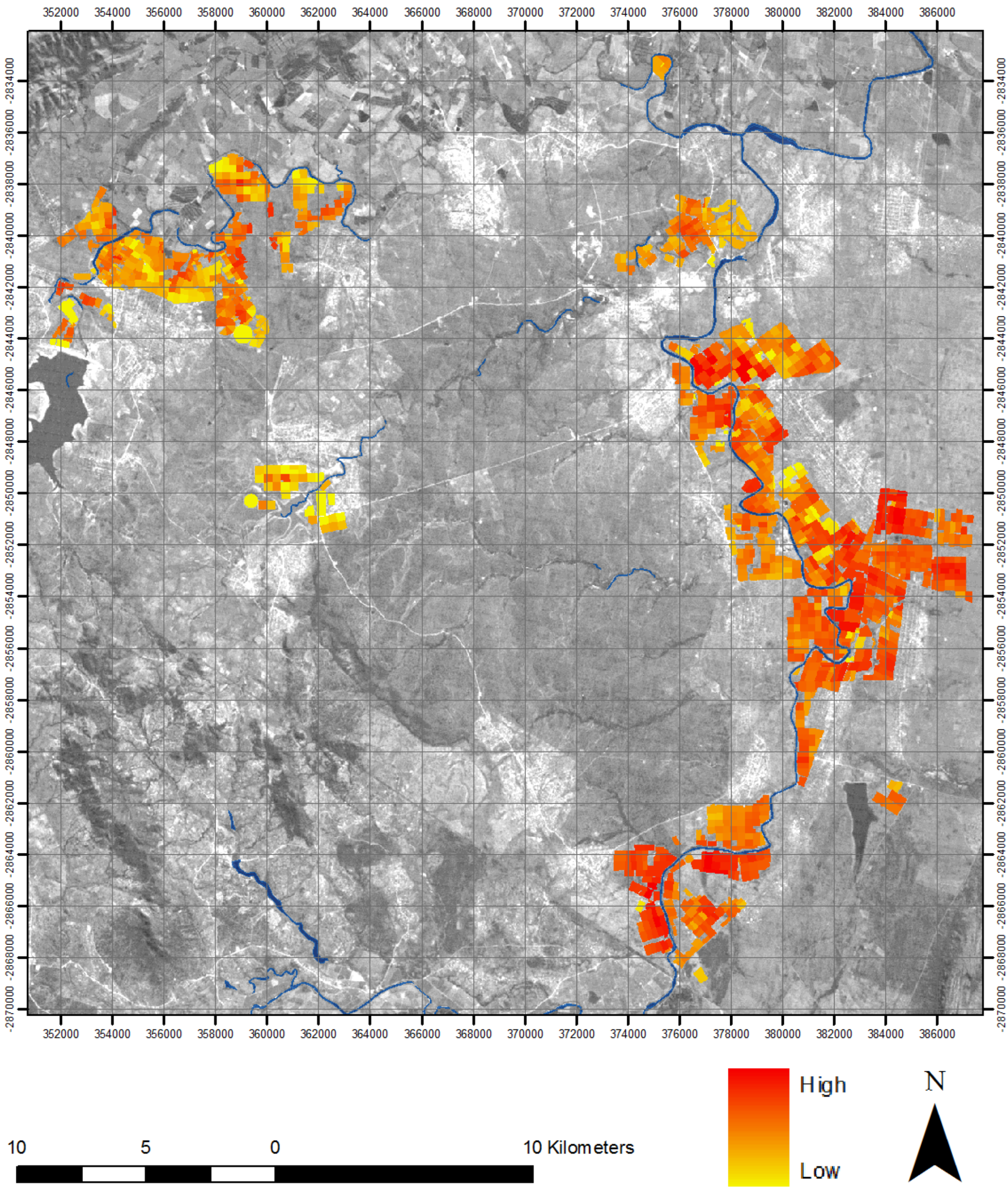
Annex II - D

Crop Water Productivity of Sugar for Commercial Farmers 2004/2005



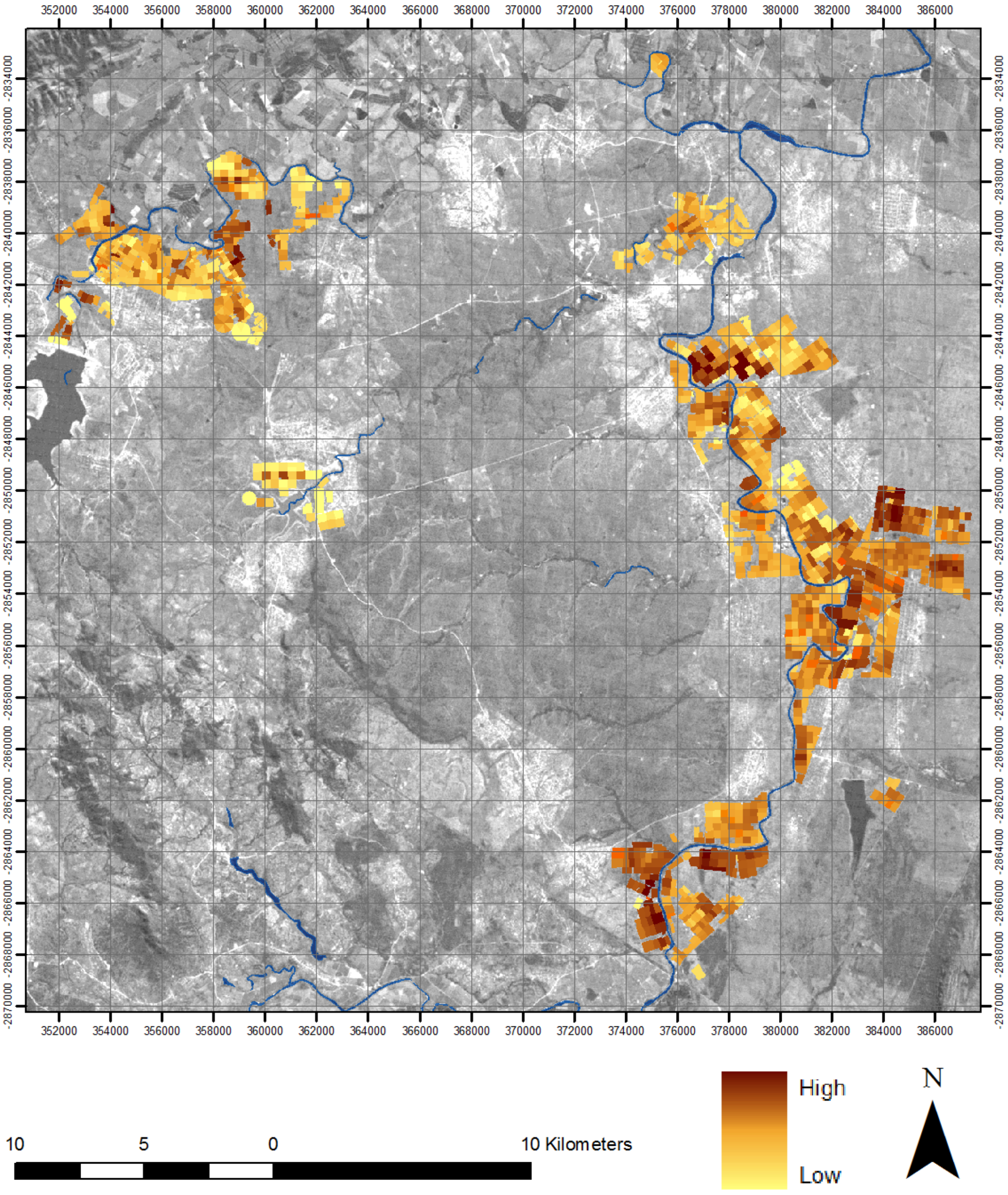
Annex II - E

Evapotranspiration of Sugar Fields for Emerging Farmers 2004/2005



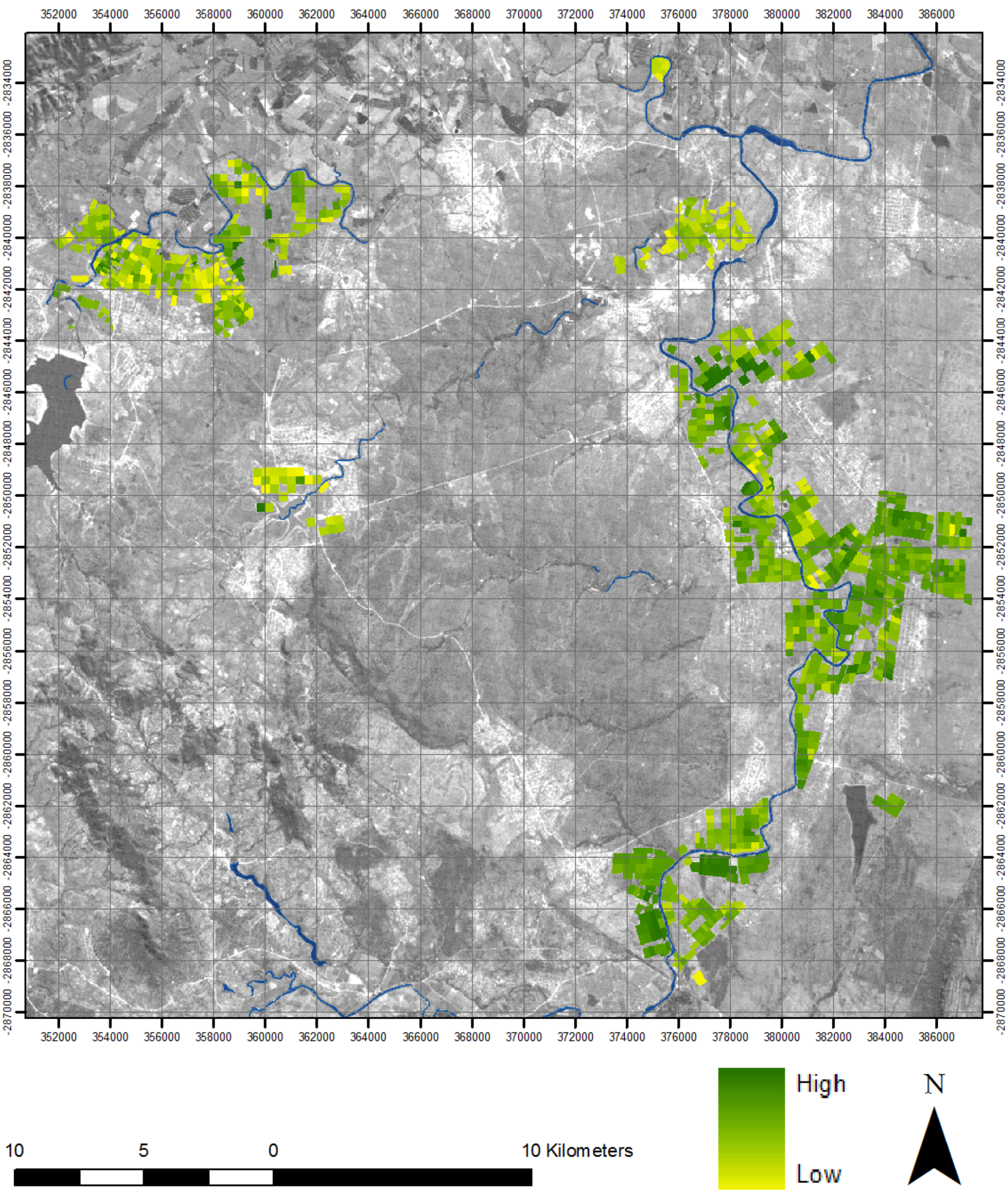
Annex II - F

Biomass Production of Sugar for Emerging Farmers 2004/2005



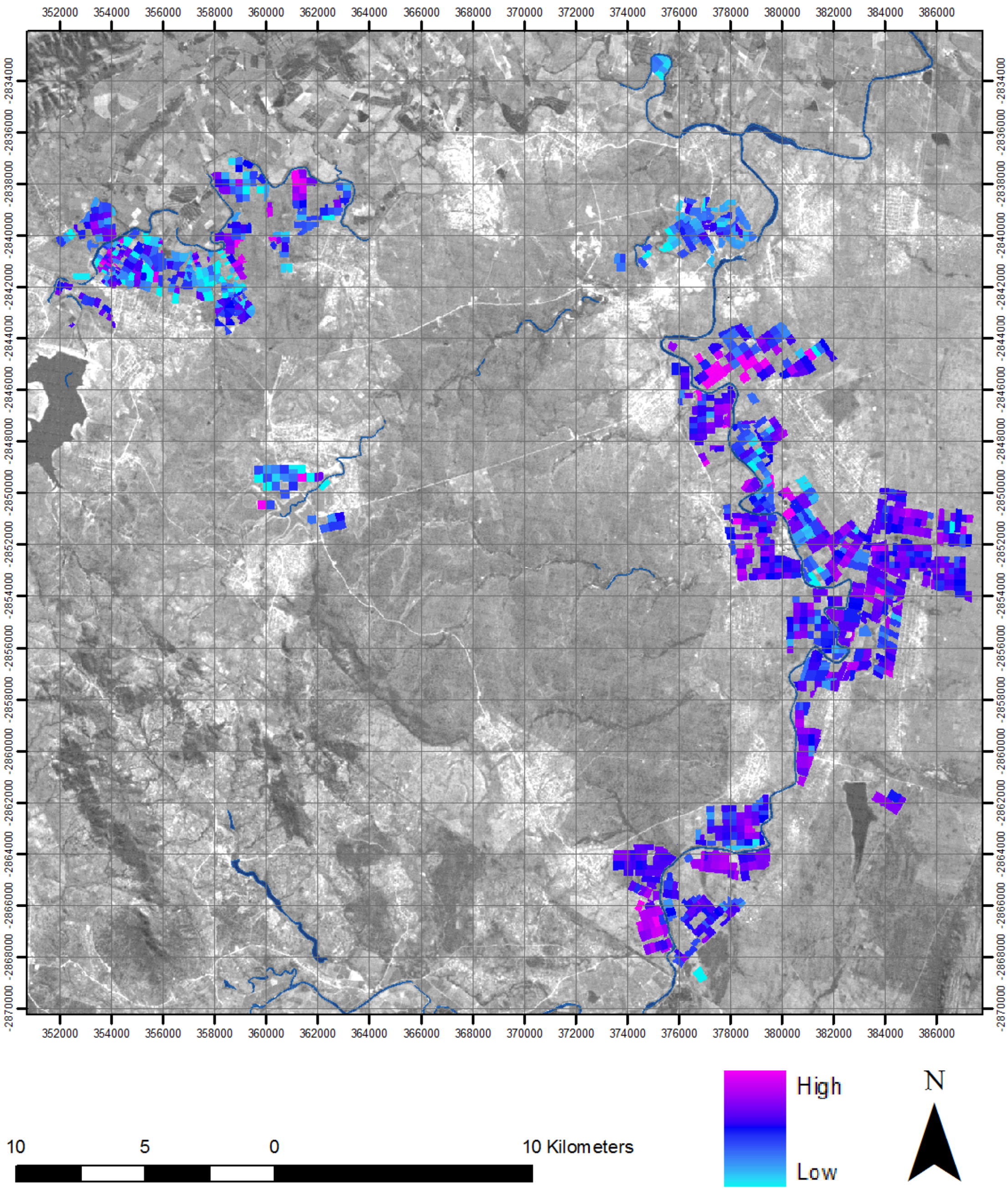
Annex II - G

Sugar Yield for Emerging Farmers 2004/2005



Annex II - H

Crop Water Productivity of Sugar for Emerging Farmers 2004/2005



ANNEX III - A

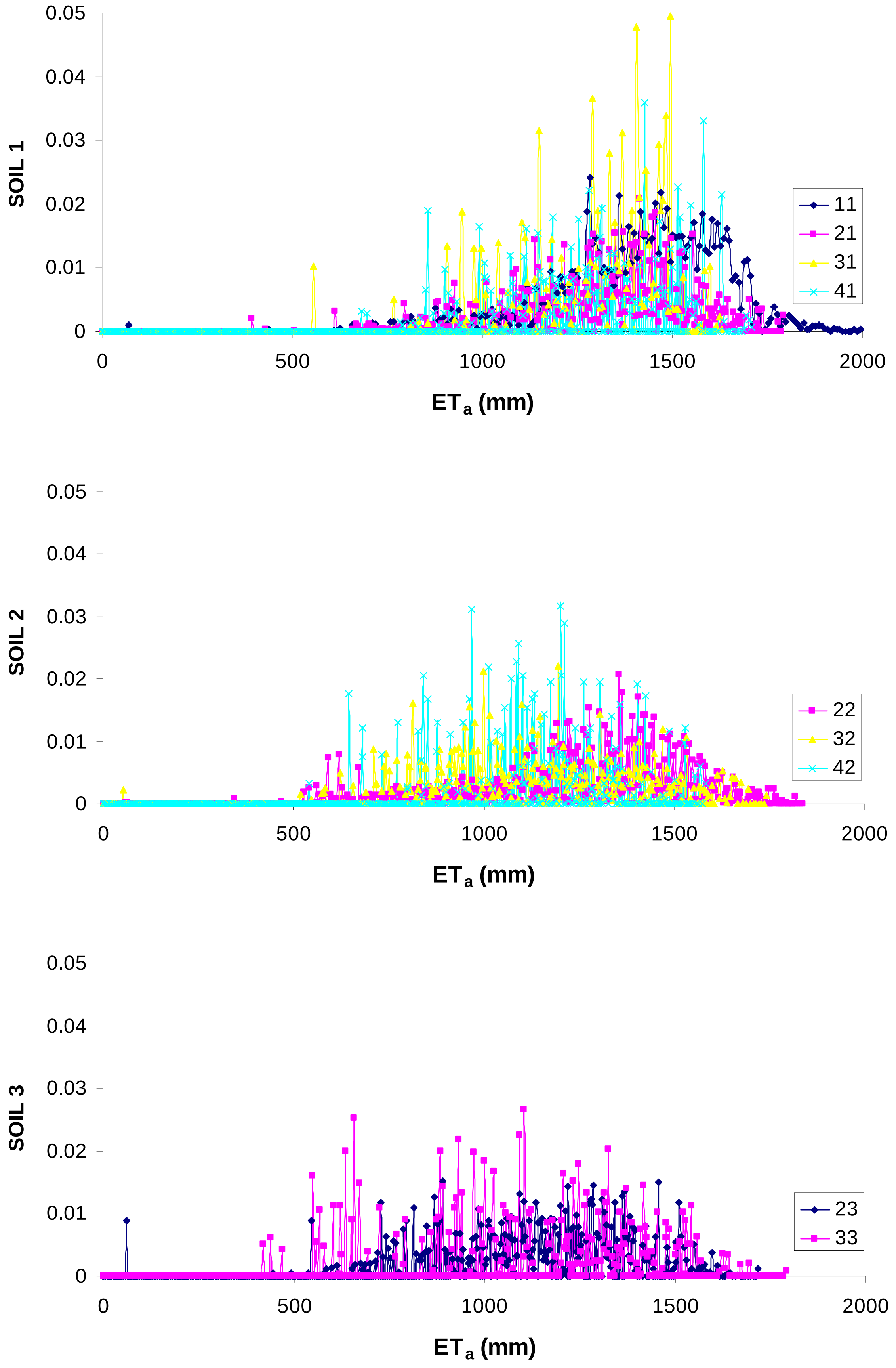


Figure A1: Histograms showing the influence of climate on values of ET_a.

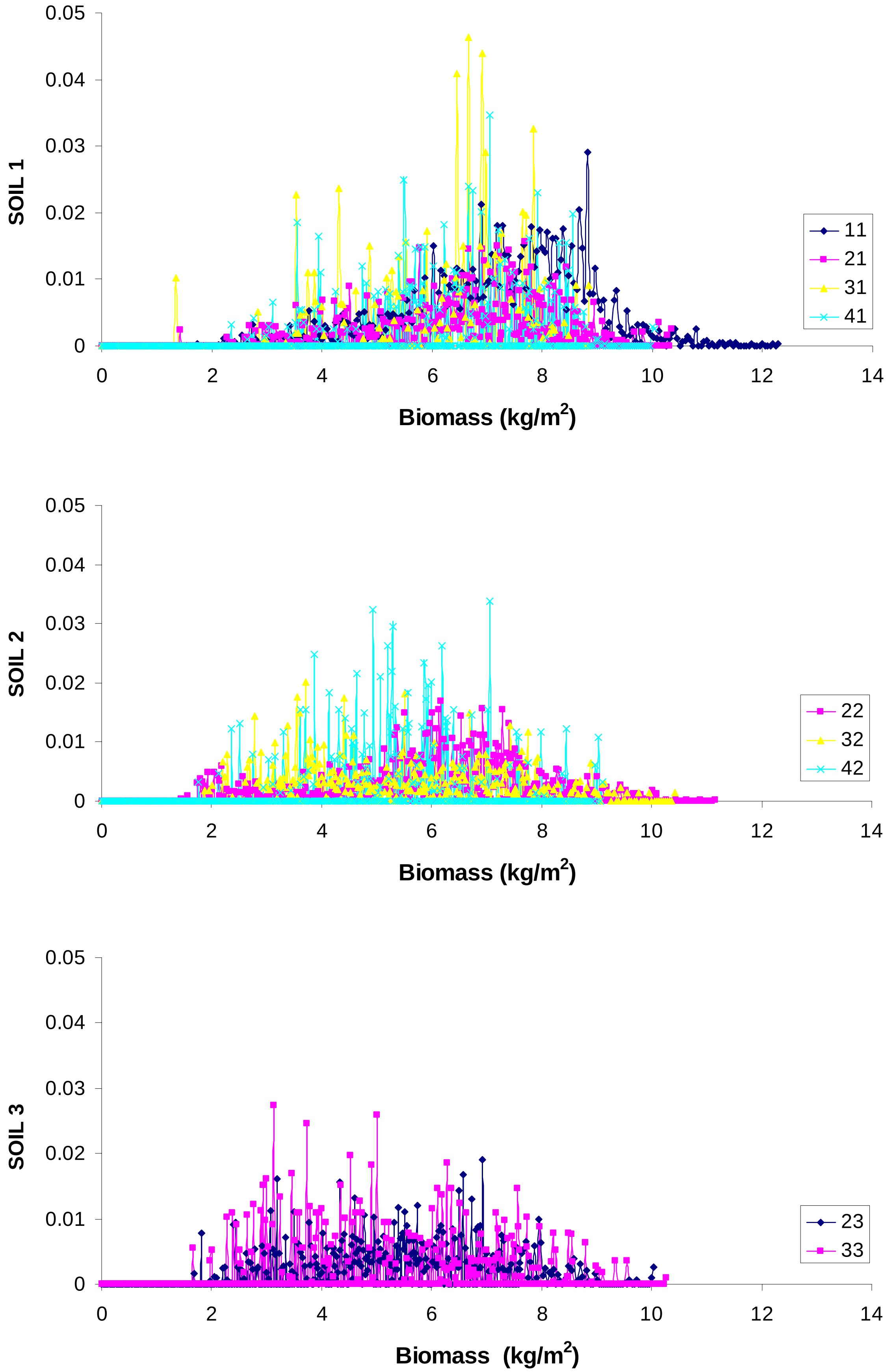


Figure A2: Histograms showing the influence of climate on values of biomass.

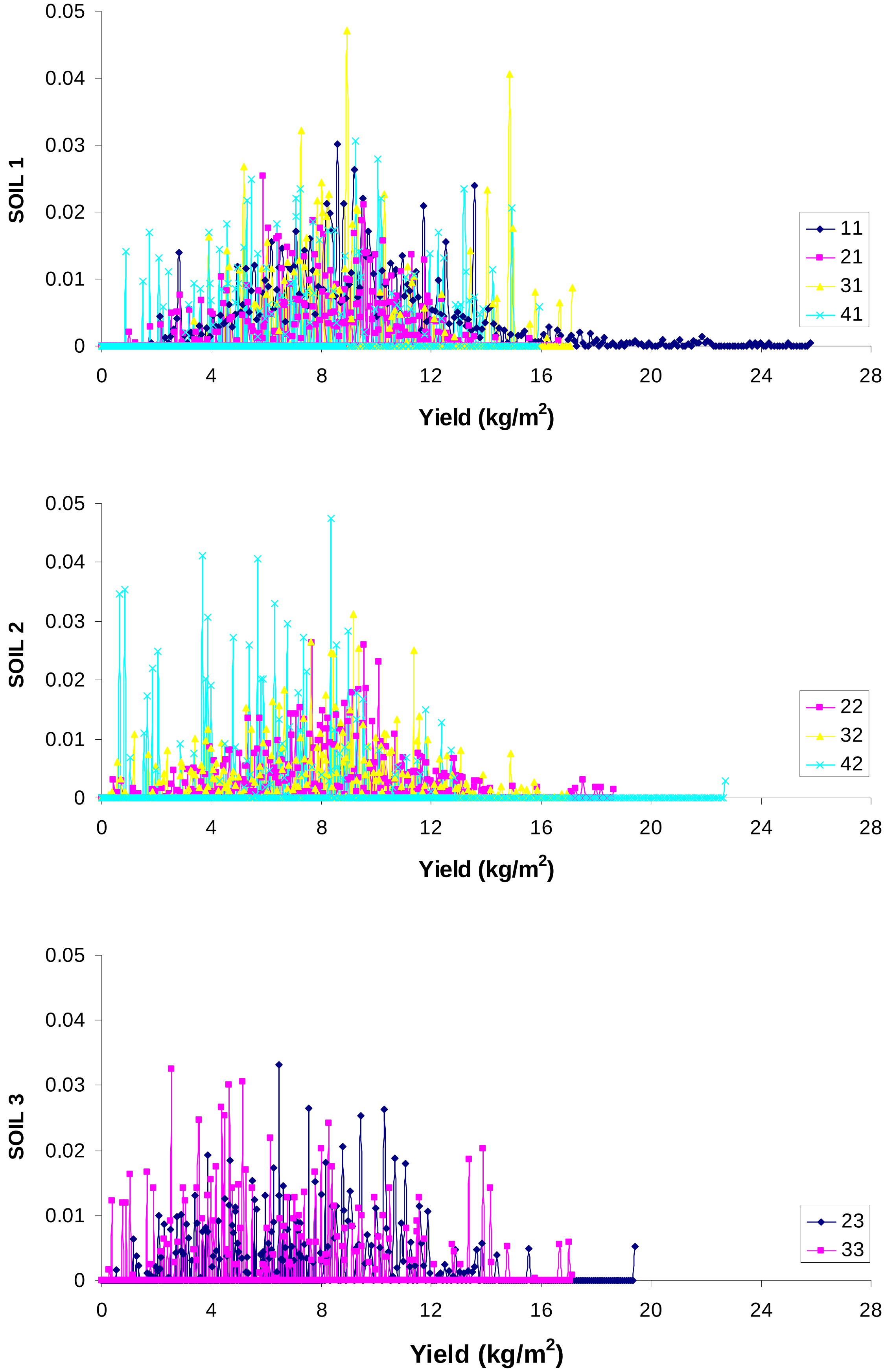


Figure A3: Histograms showing the influence of climate on values of yield production.

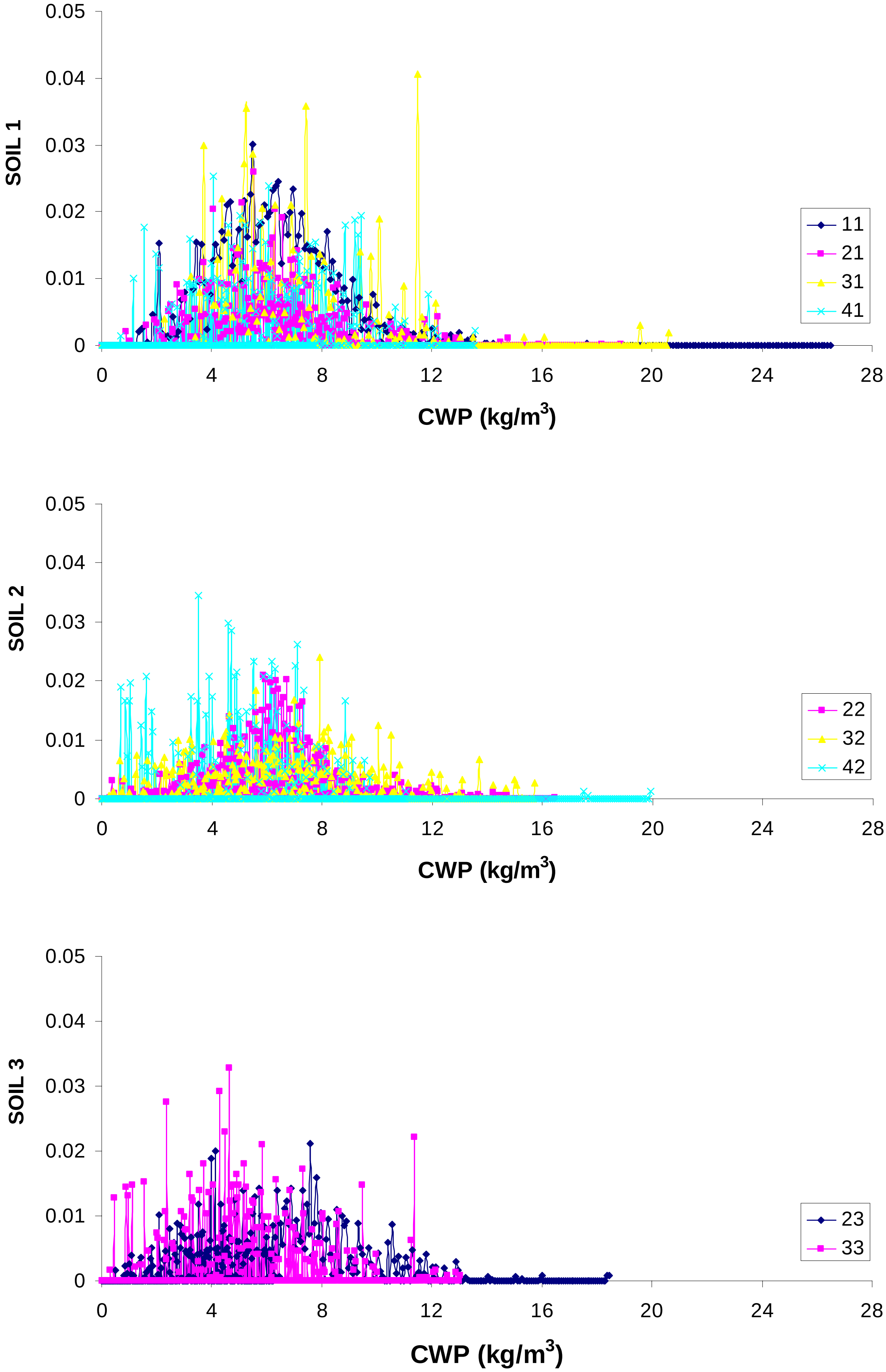


Figure A4: Histograms showing the influence of climate on values of CWP.

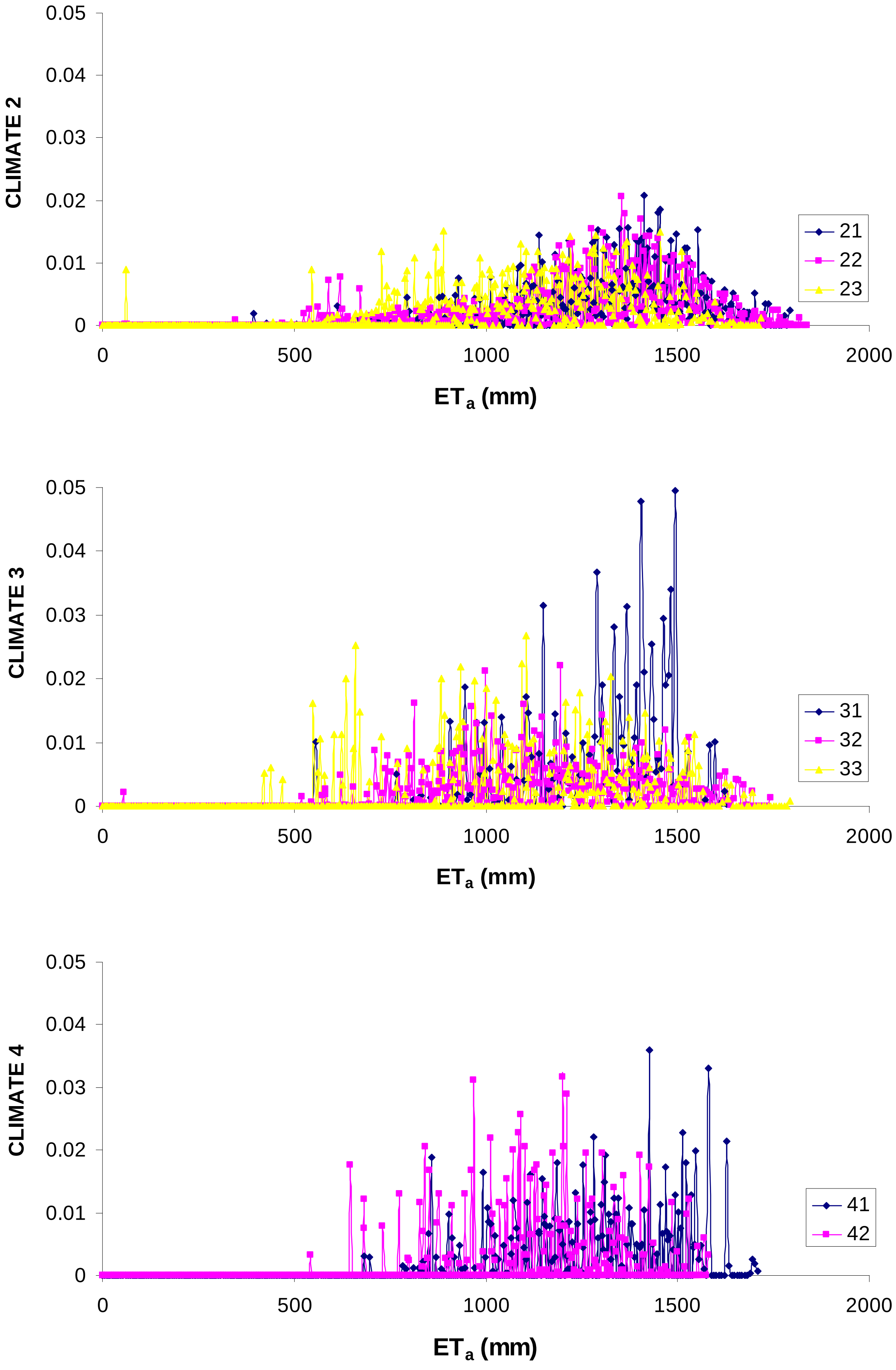


Figure A5: Histograms showing the influence of soil class on values of ET_a.

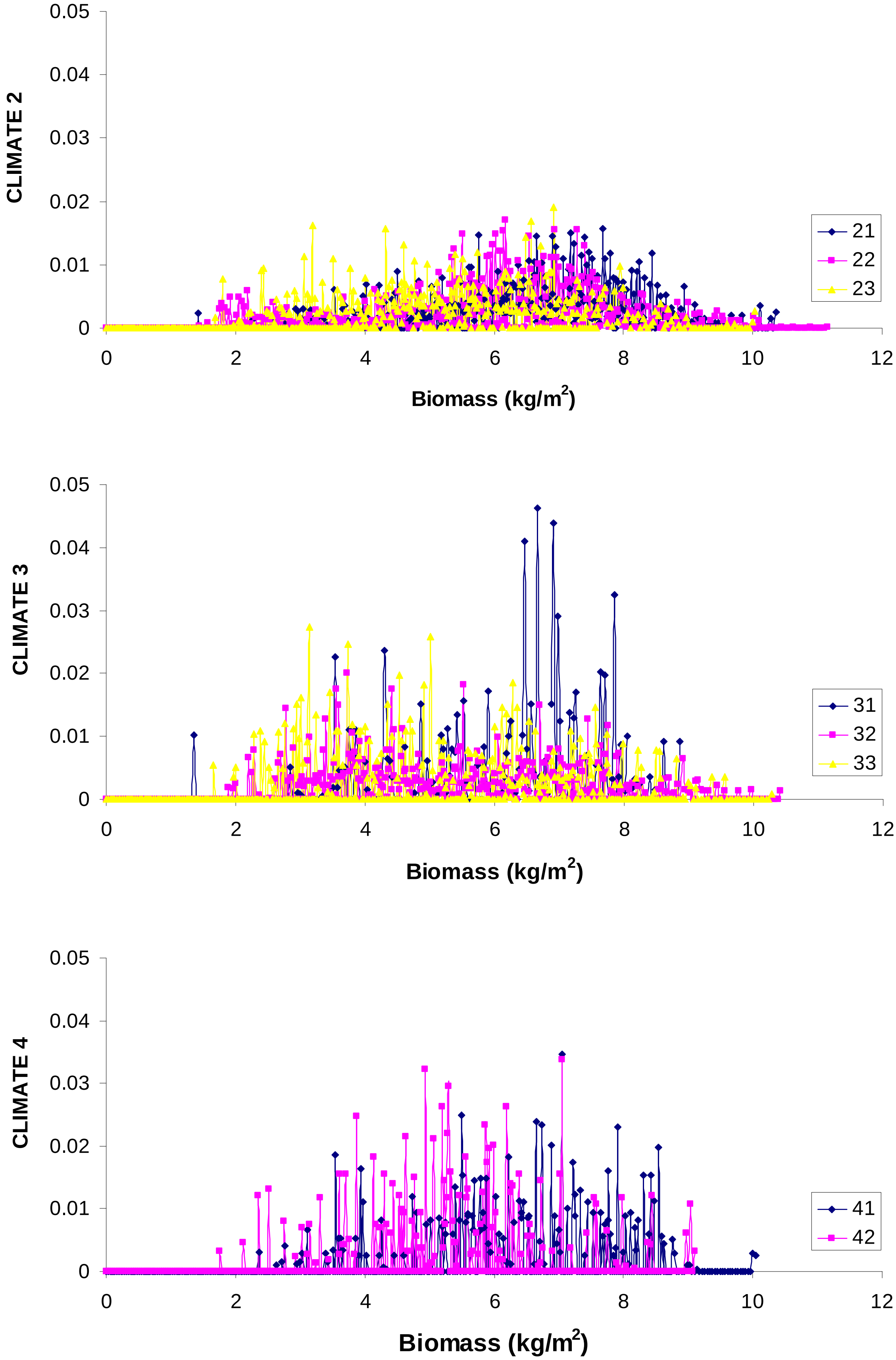


Figure A6: Histograms showing the influence of soil class on values of biomass.

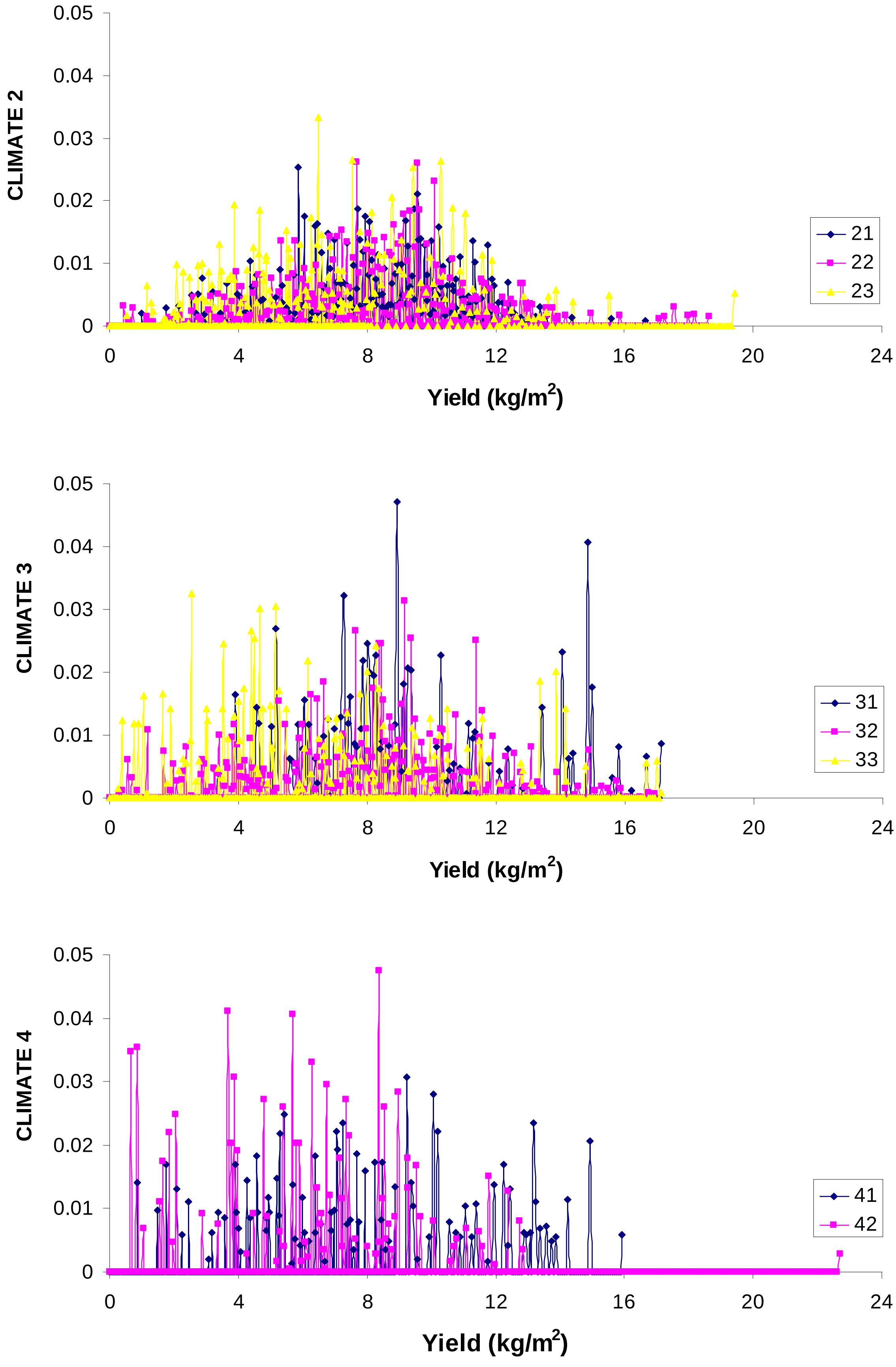


Figure A7: Histograms showing the influence of soil class on values of yield production.

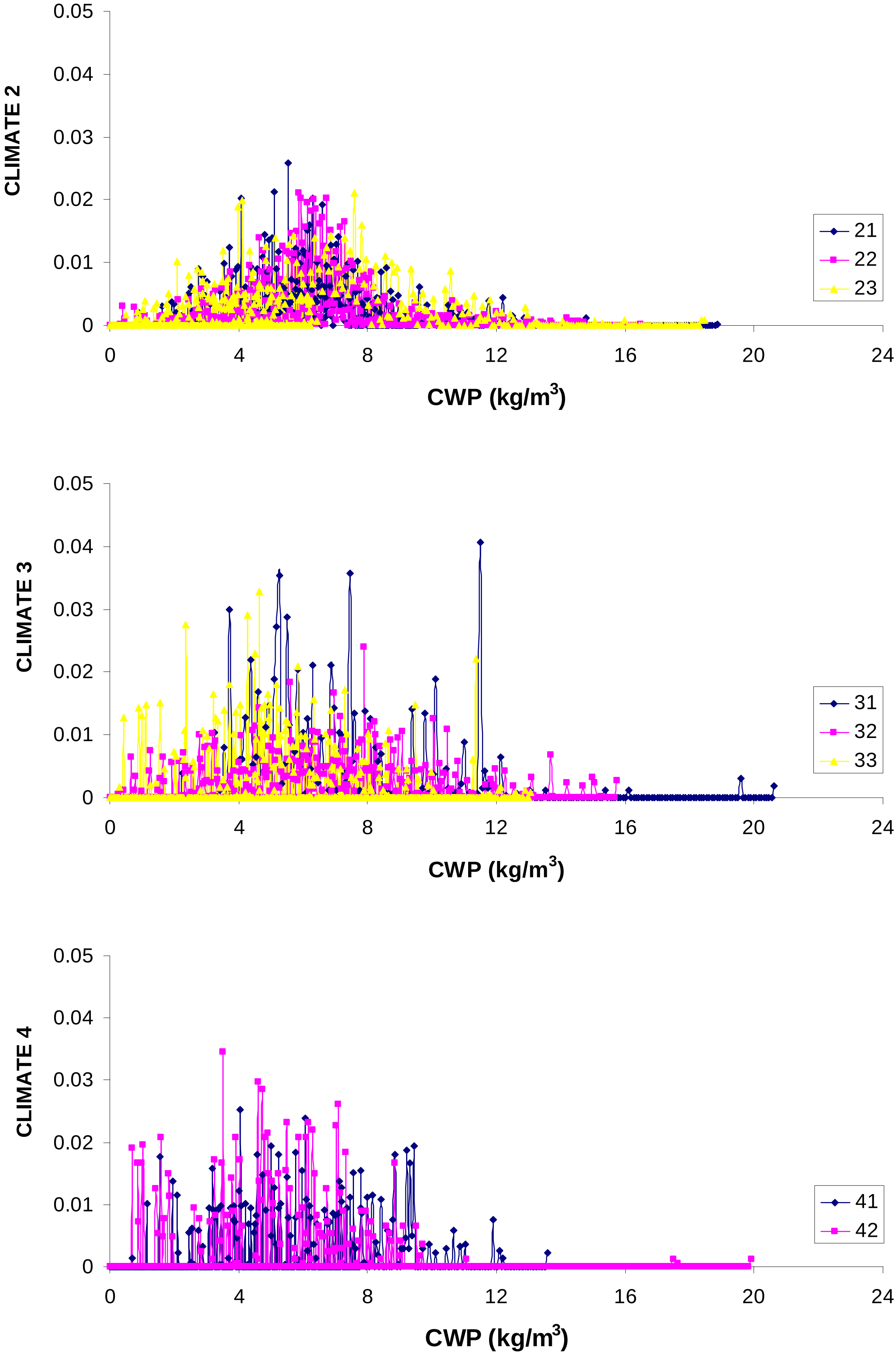


Figure A8: Histograms showing the influence of soil class on values of CWP.

ANNEX III - B

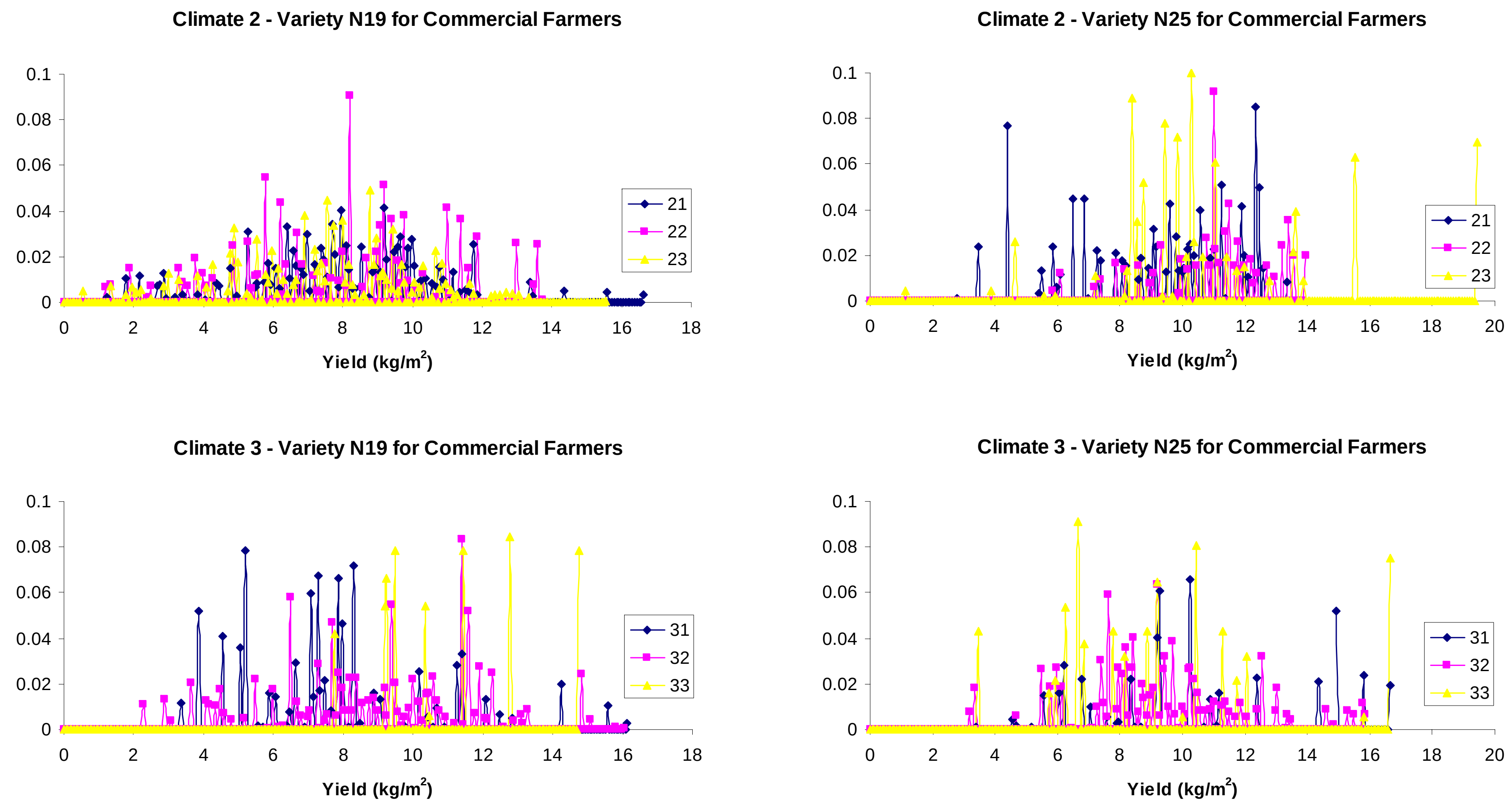
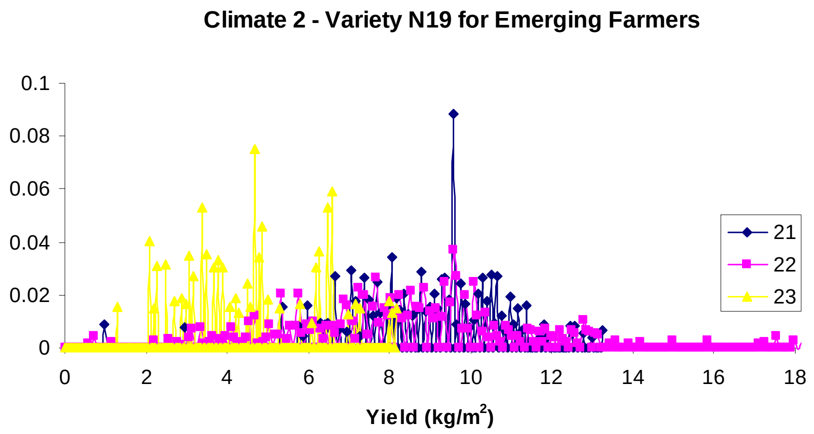
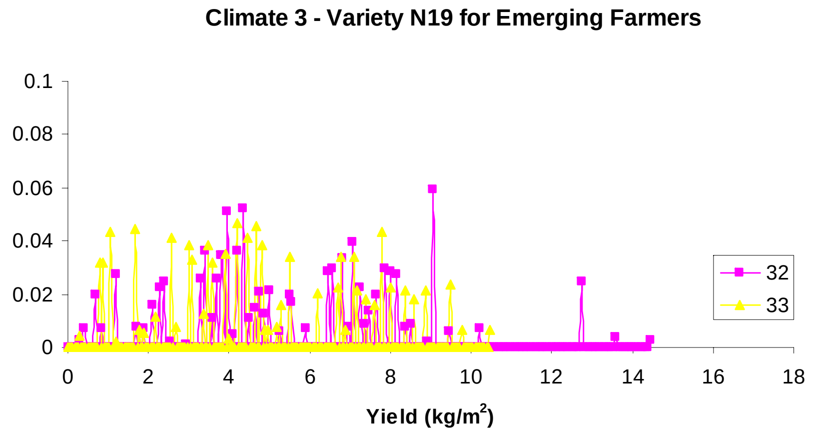


Figure B1: Histograms showing the influence of soil class on yield production of N19 and N25 for commercial farmers.





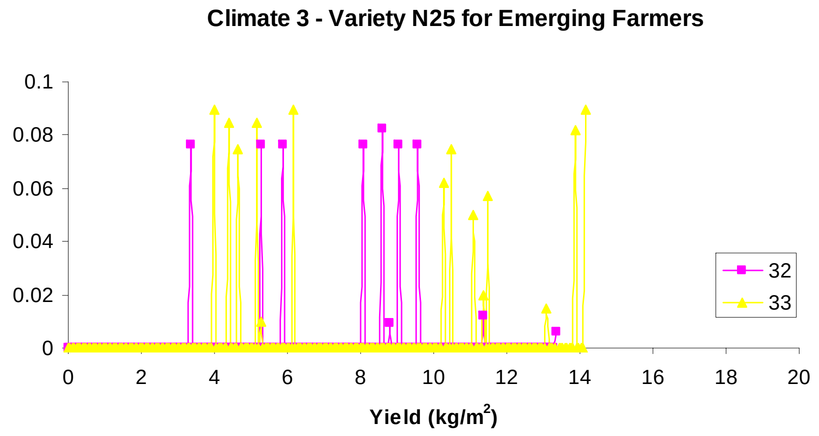


Figure B2: Histograms showing the influence of soil class on yield production of N19 and N25 for emerging farmers.

ANNEX III - C

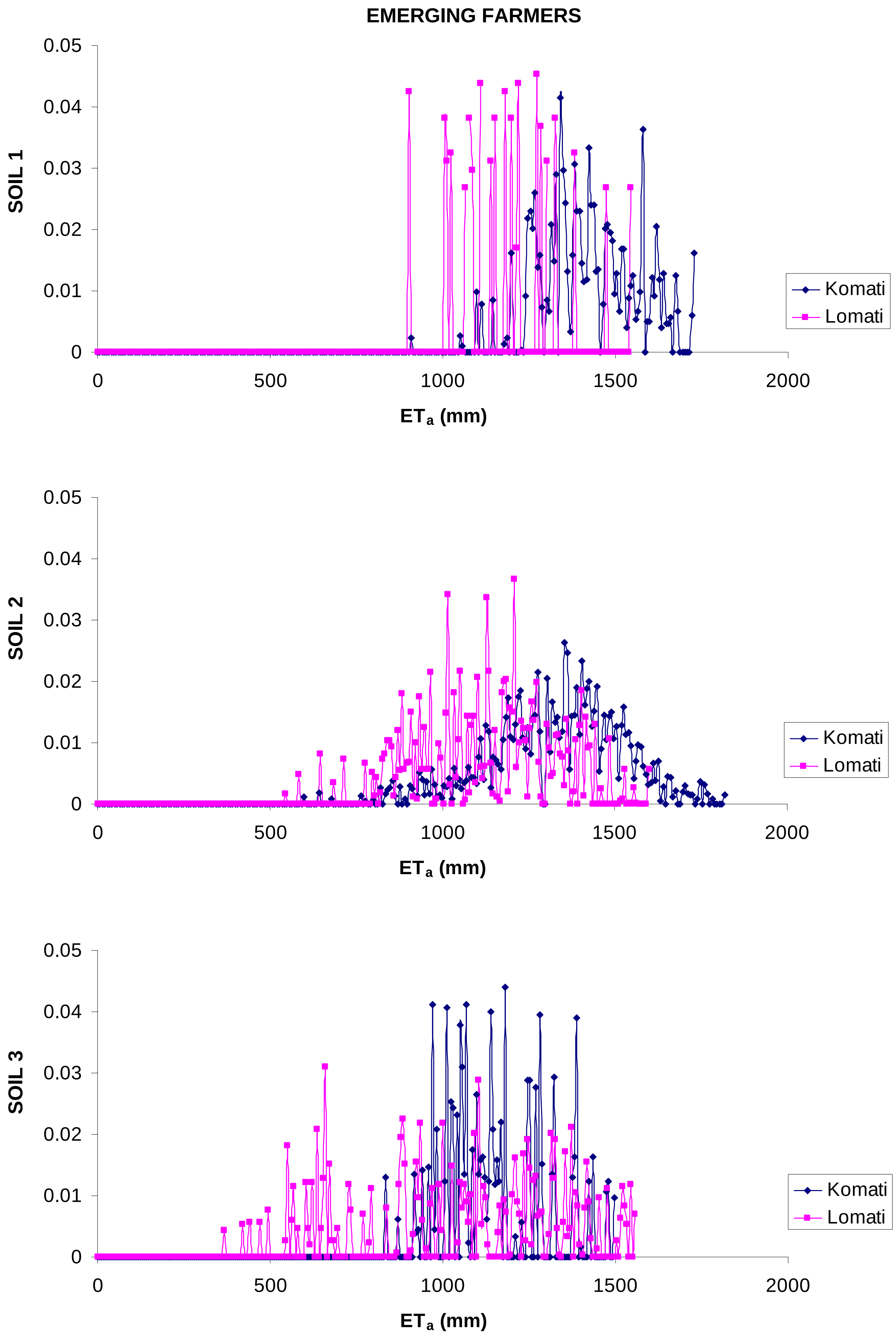


Figure C1: Histograms showing the influence of river allocations on values of ET_a for emerging farmers.

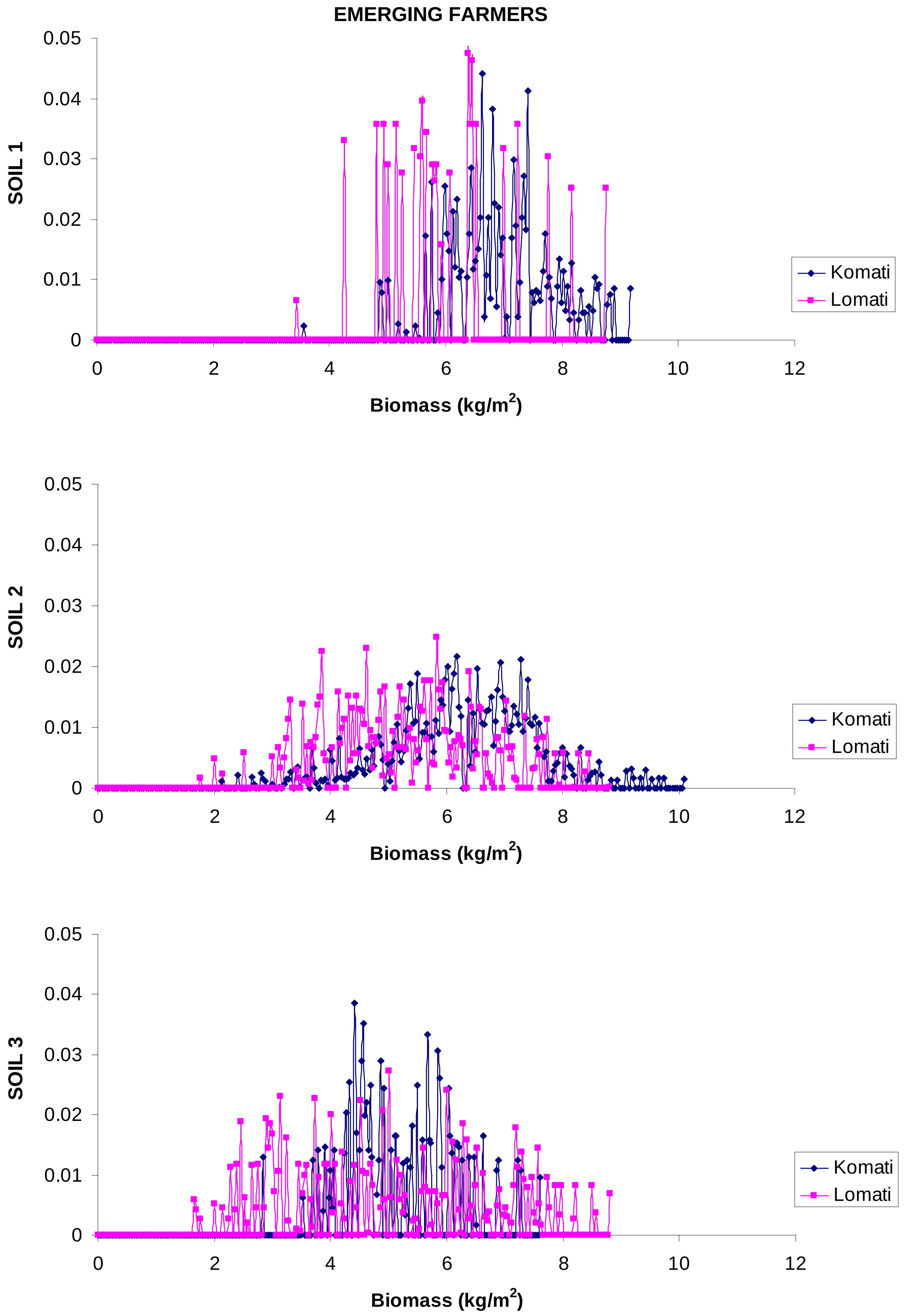


Figure C2: Histograms showing the influence of river allocations on values of biomass for emerging farmers.

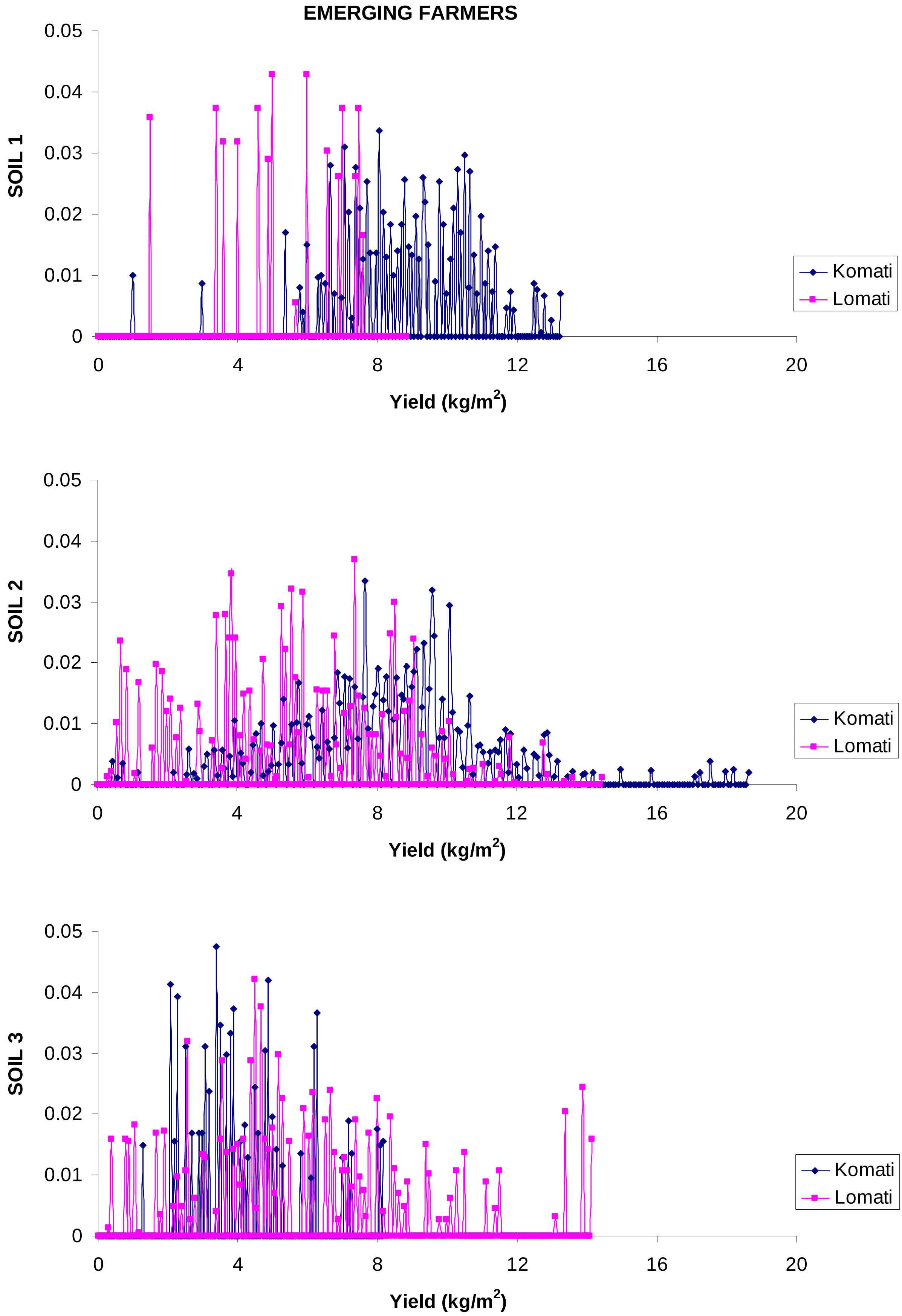


Figure C3: Histograms showing the influence of river allocations on values of yield production for emerging farmers.

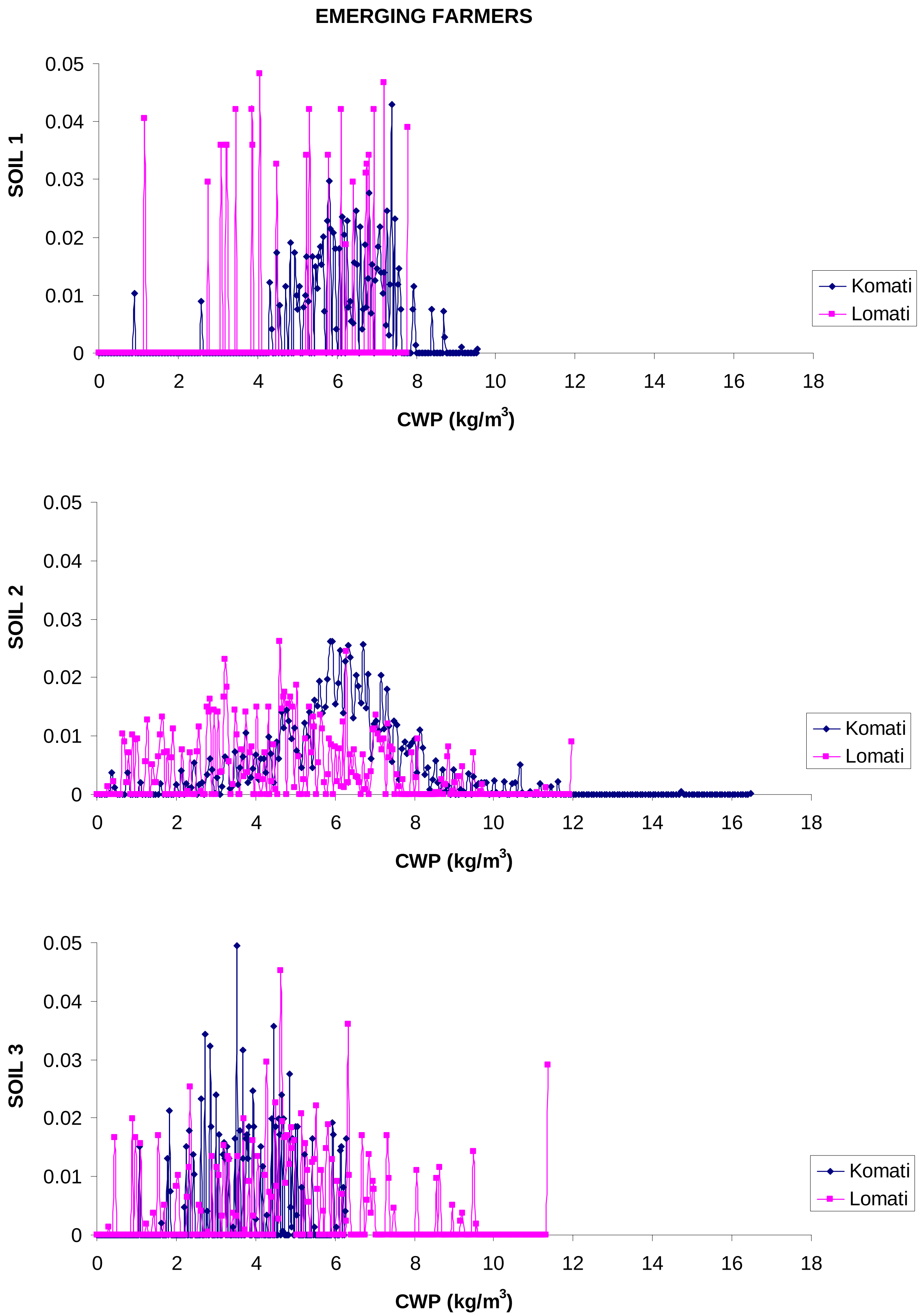


Figure C4: Histograms showing the influence of river allocations on values of CWP for emerging farmers.

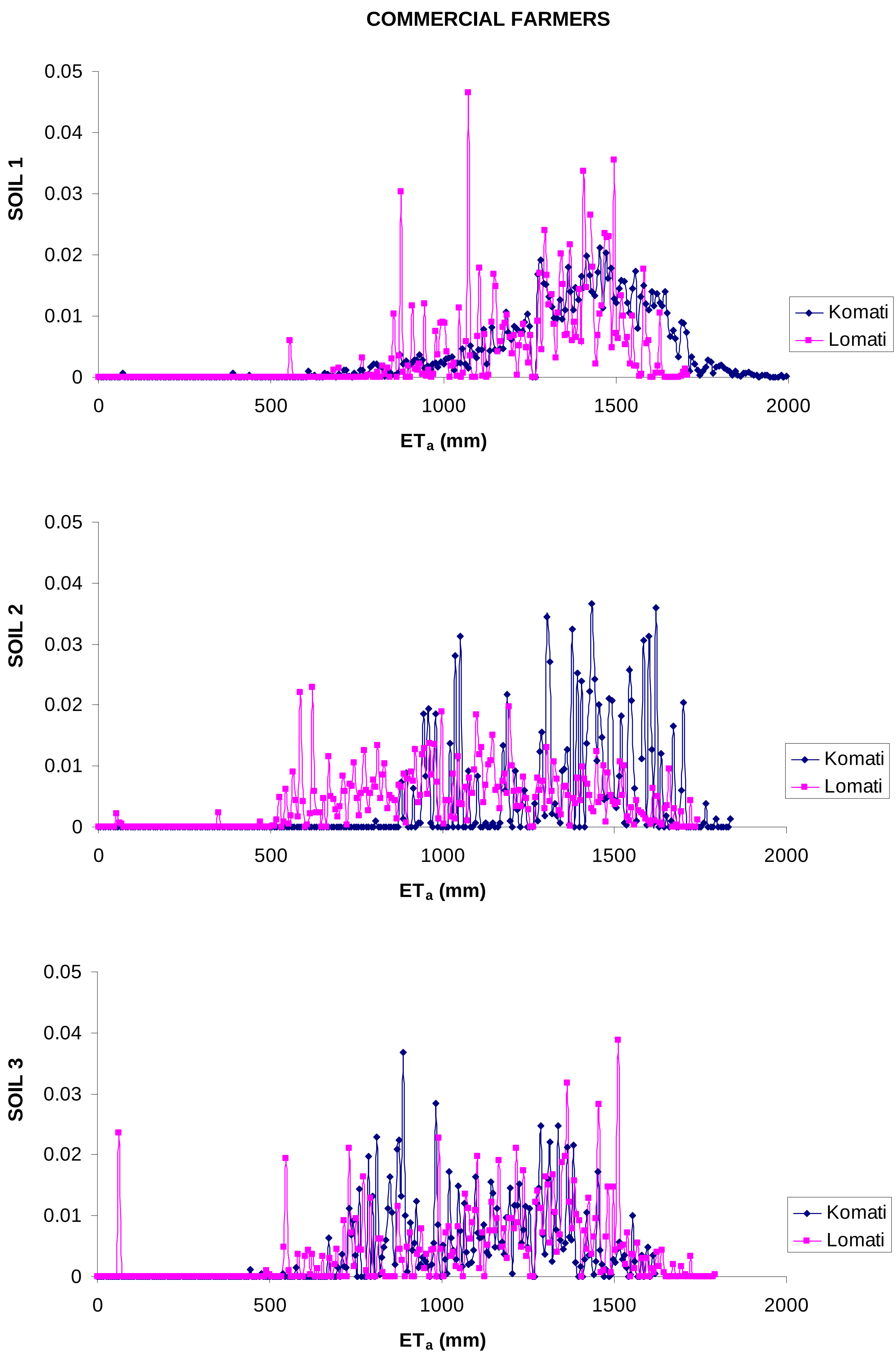


Figure C5: Histograms showing the influence of river allocations on values of ET_a for commercial farmers.

COMMERCIAL FARMERS

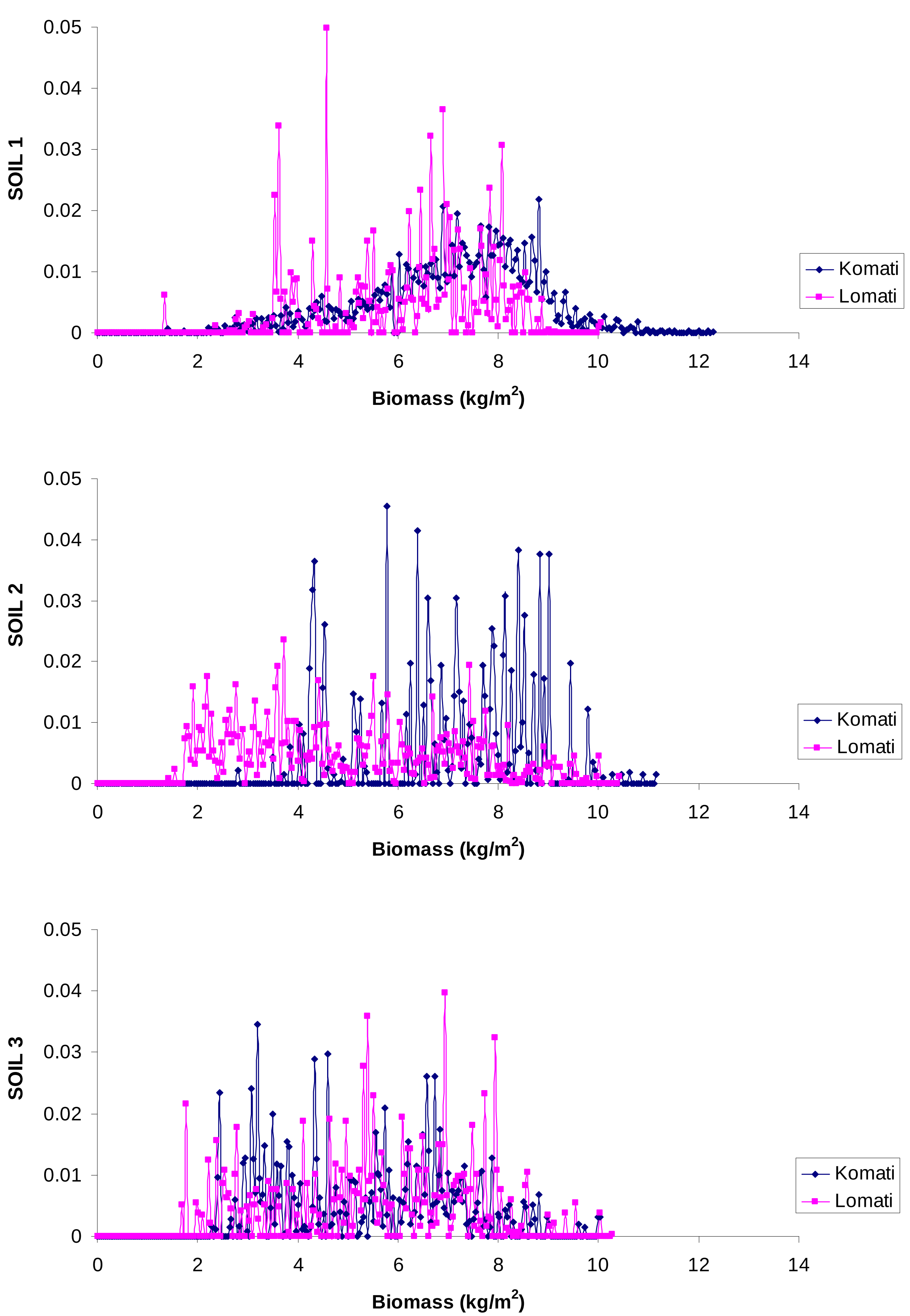


Figure C6: Histograms showing the influence of river allocations on values of biomass for commercial farmers.

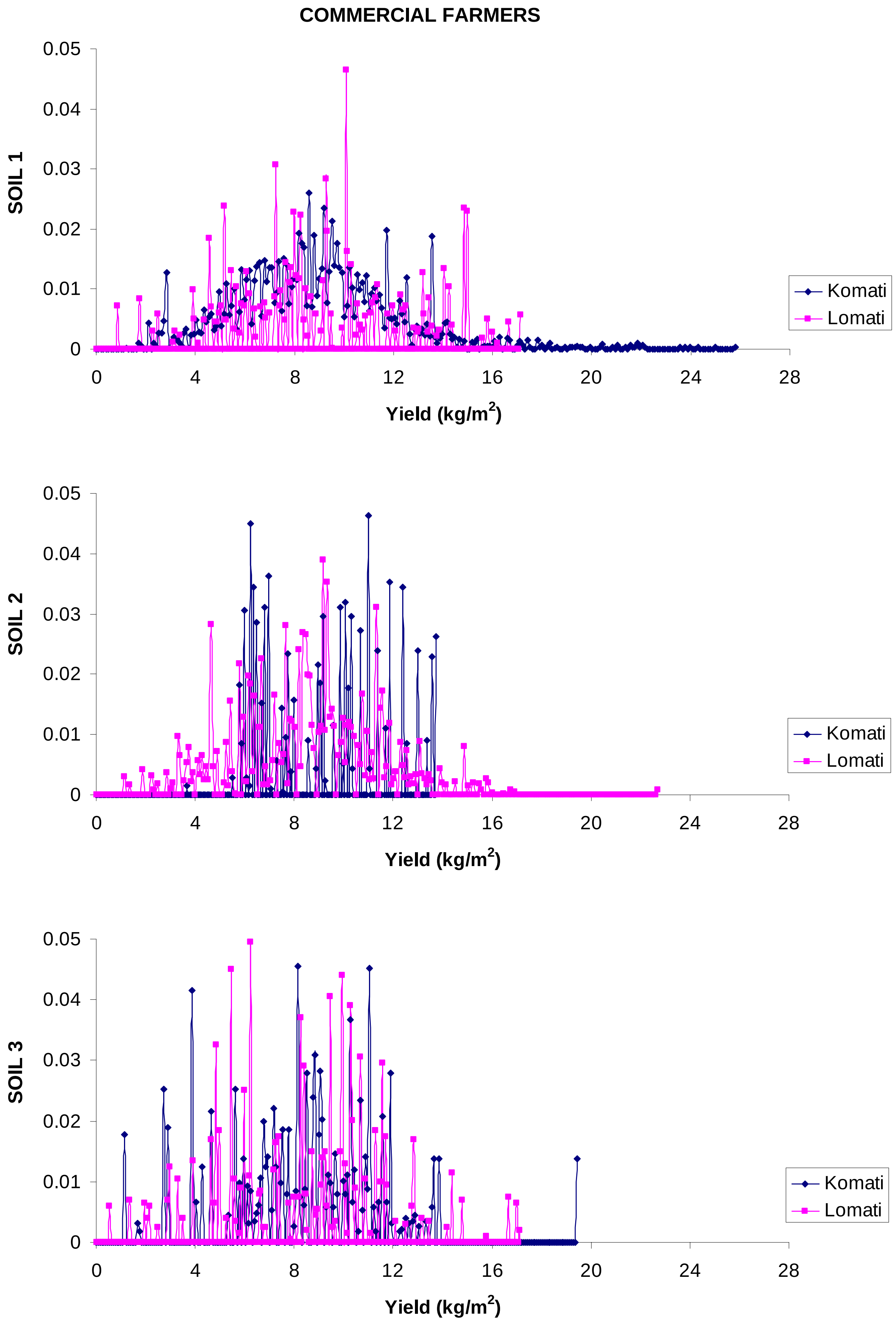


Figure C7: Histograms showing the influence of river allocations on values of yield production for commercial farmers.

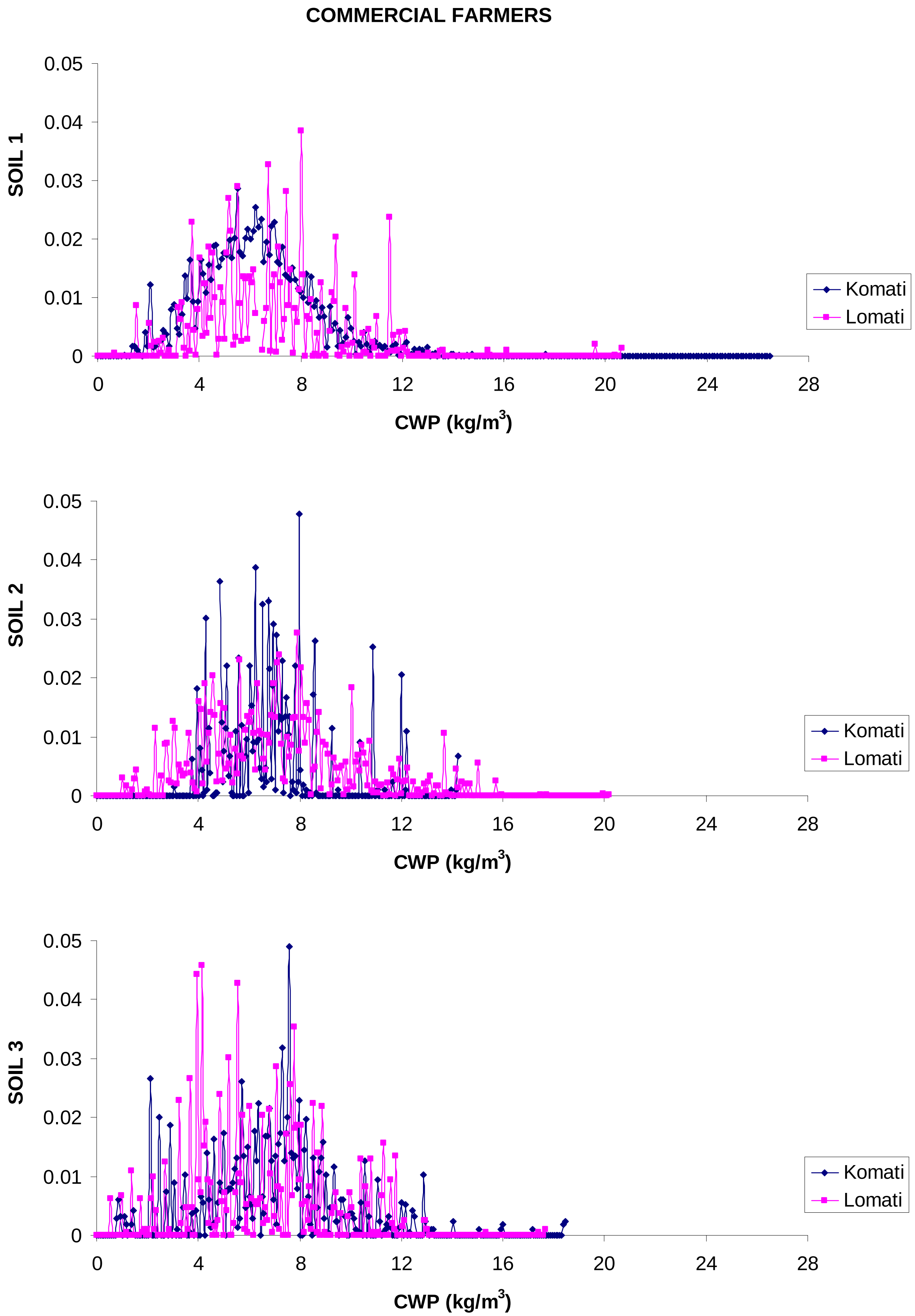


Figure C8: Histograms showing the influence of river allocations on values of CWP for commercial farmers.

ANNEX III – D

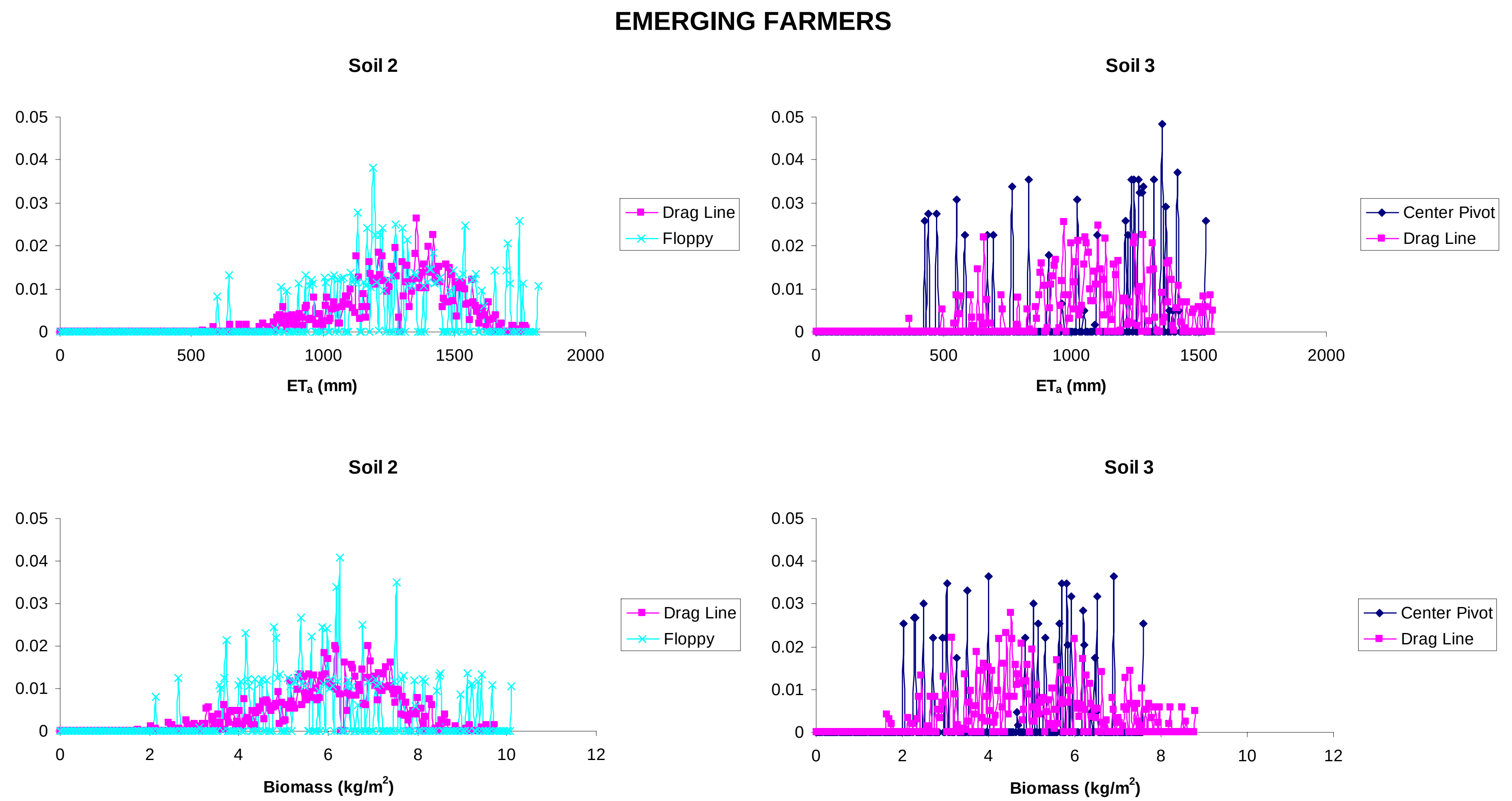


Figure D1: Histograms showing the influence of irrigation type on values of ET_a and biomass for emerging farmers in soil class 2 and 3.

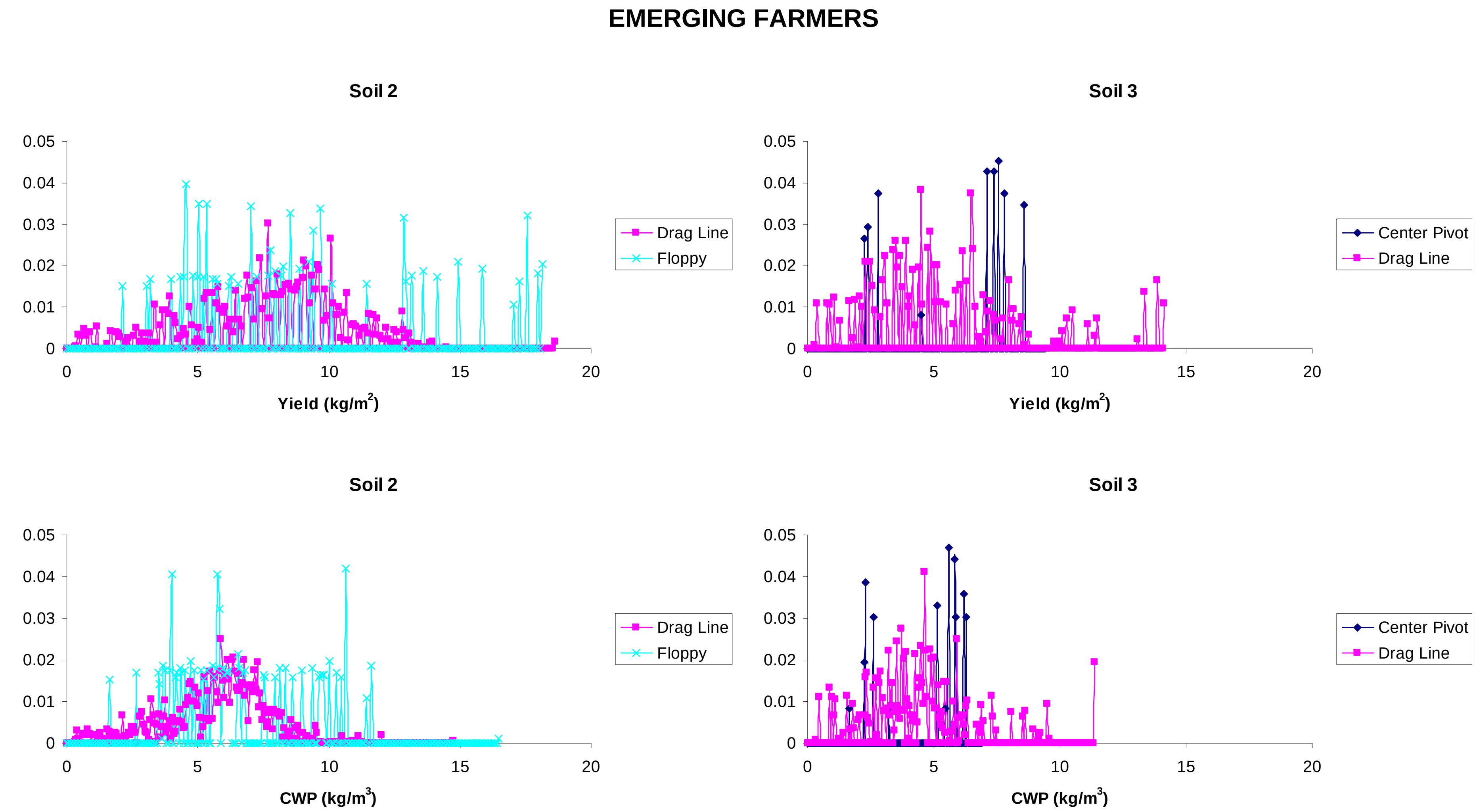


Figure D2: Histograms showing the influence of irrigation type on values of yield production and CWP for emerging farmers in soil class 2 and 3.

COMMERCIAL FARMERS - SOIL CLASS 1

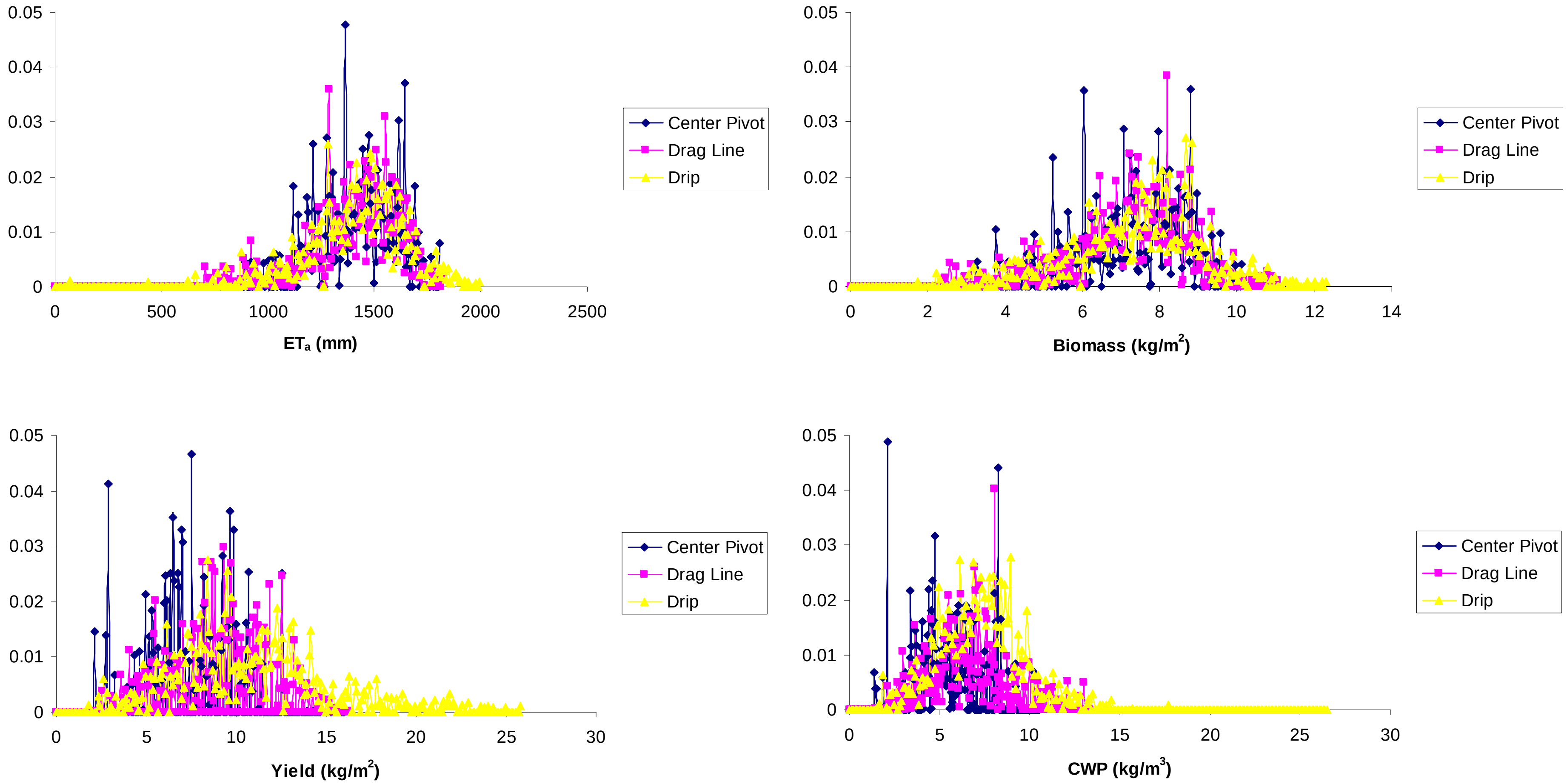


Figure D4: Histograms showing the influence of irrigation type on values of ET_a, biomass, yield production and CWP for commercial farmers in soil class 1.

COMMERCIAL FARMERS – SOIL CLASS 2

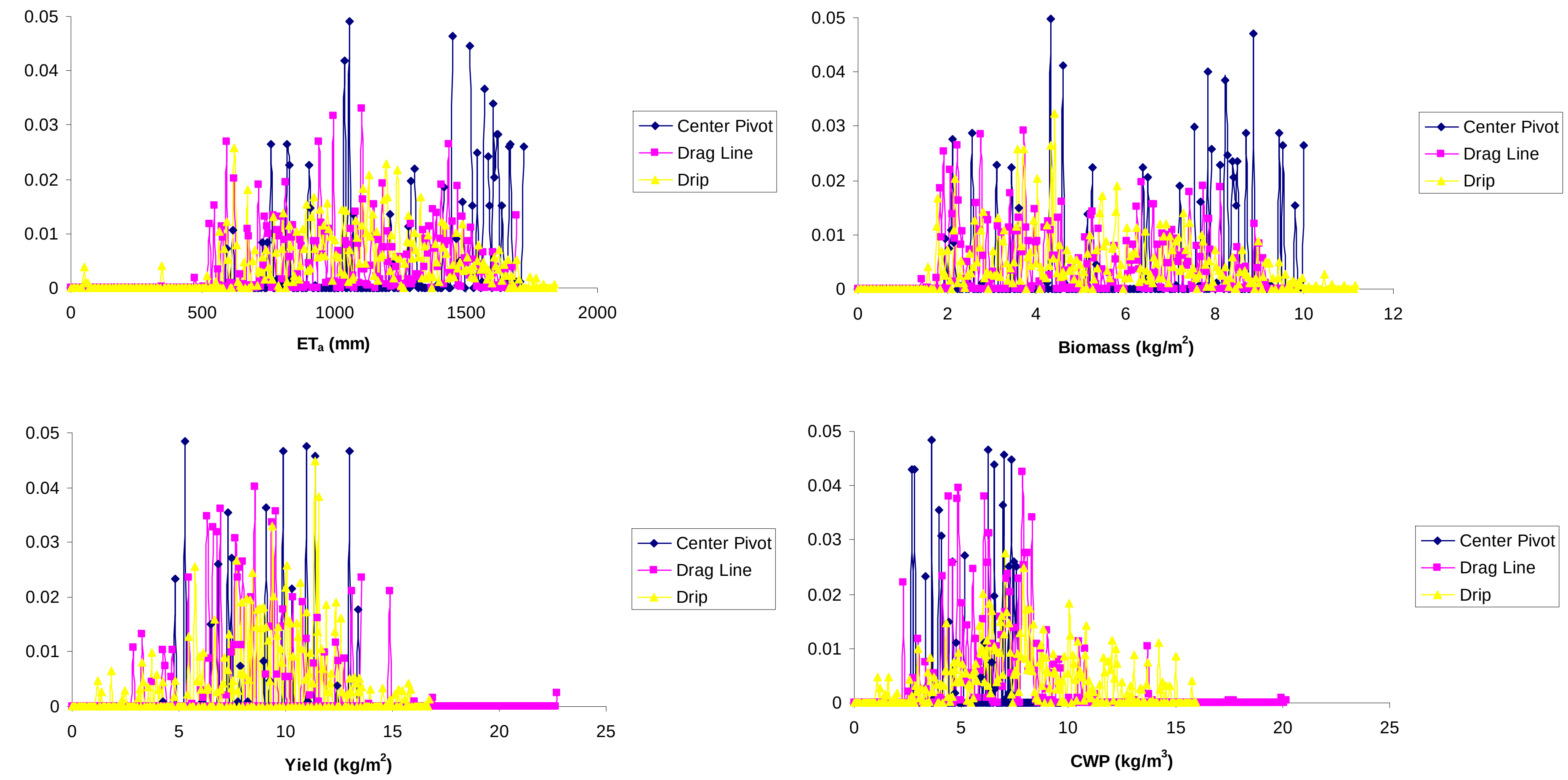
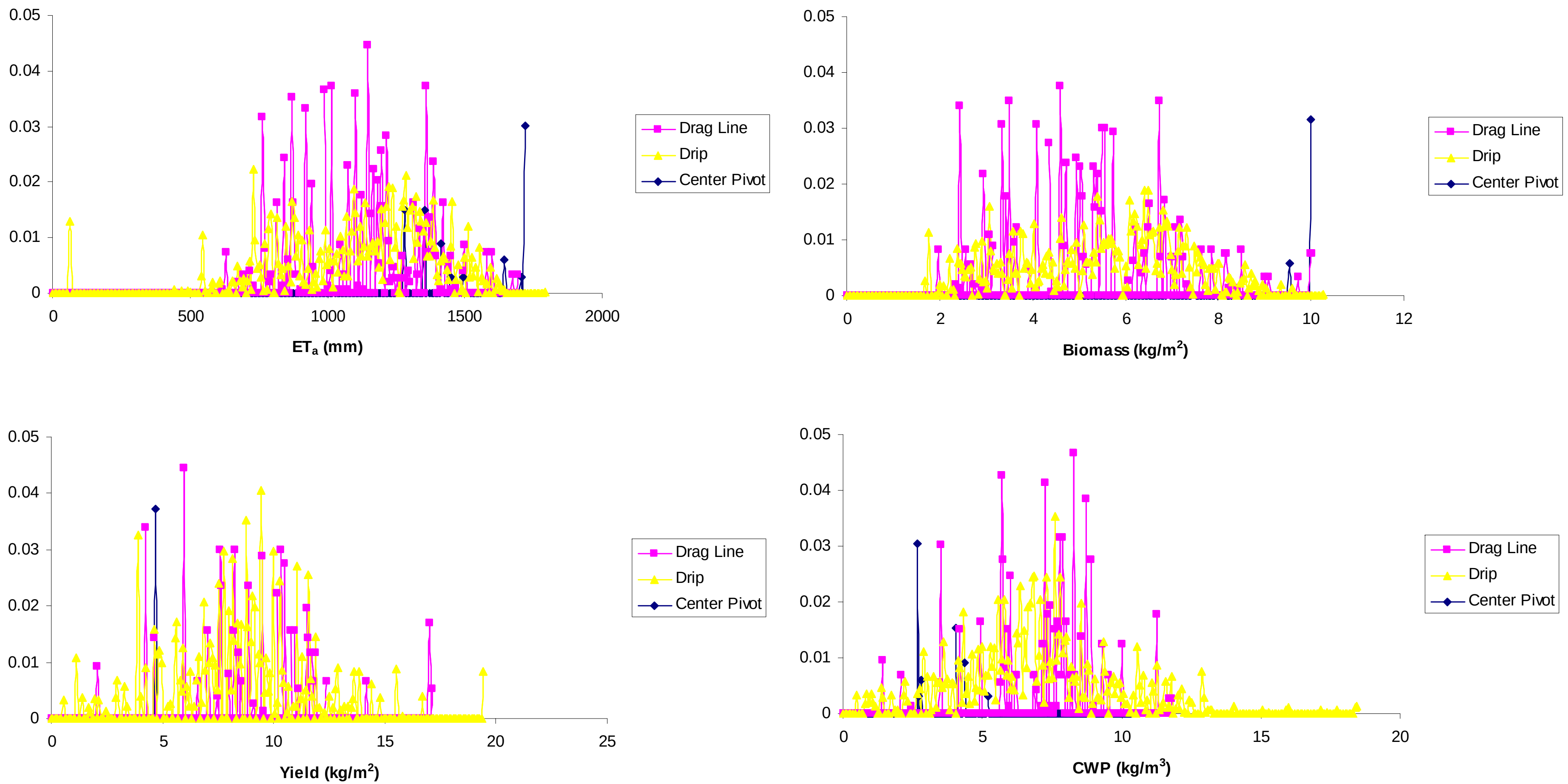


Figure D5: Histograms showing the influence of irrigation type on values of ET_a, biomass, yield production and CWP for commercial farmers in soil class 2.

COMMERCIAL FARMERS – SOIL CLASS 3



D6: Histograms showing the influence of irrigation type on values of ET_a, biomass, yield production and CWP for commercial farmers in soil class 3.

ANNEX IV – LEGEND – COMMERCIAL FARMERS

SOIL CLASS 1

SOIL CLASS 2

SOIL CLASS 3

BLACK OUTLINED:
PLOTS UNDER DRIP IRRIGATION

PURPLE OUTLINED:
PLOTS UNDER PIVOT IRRIGATION

WHITE OUTLINED:
PLOTS UNDER DRAG LINE IRRIGATION

BLUE OUTLINED:
PLOTS UNDER FLOPPY IRRIGATION

ANNEX V – LEGEND – EMERGING FARMERS

SOIL CLASS 1

SOIL CLASS 2

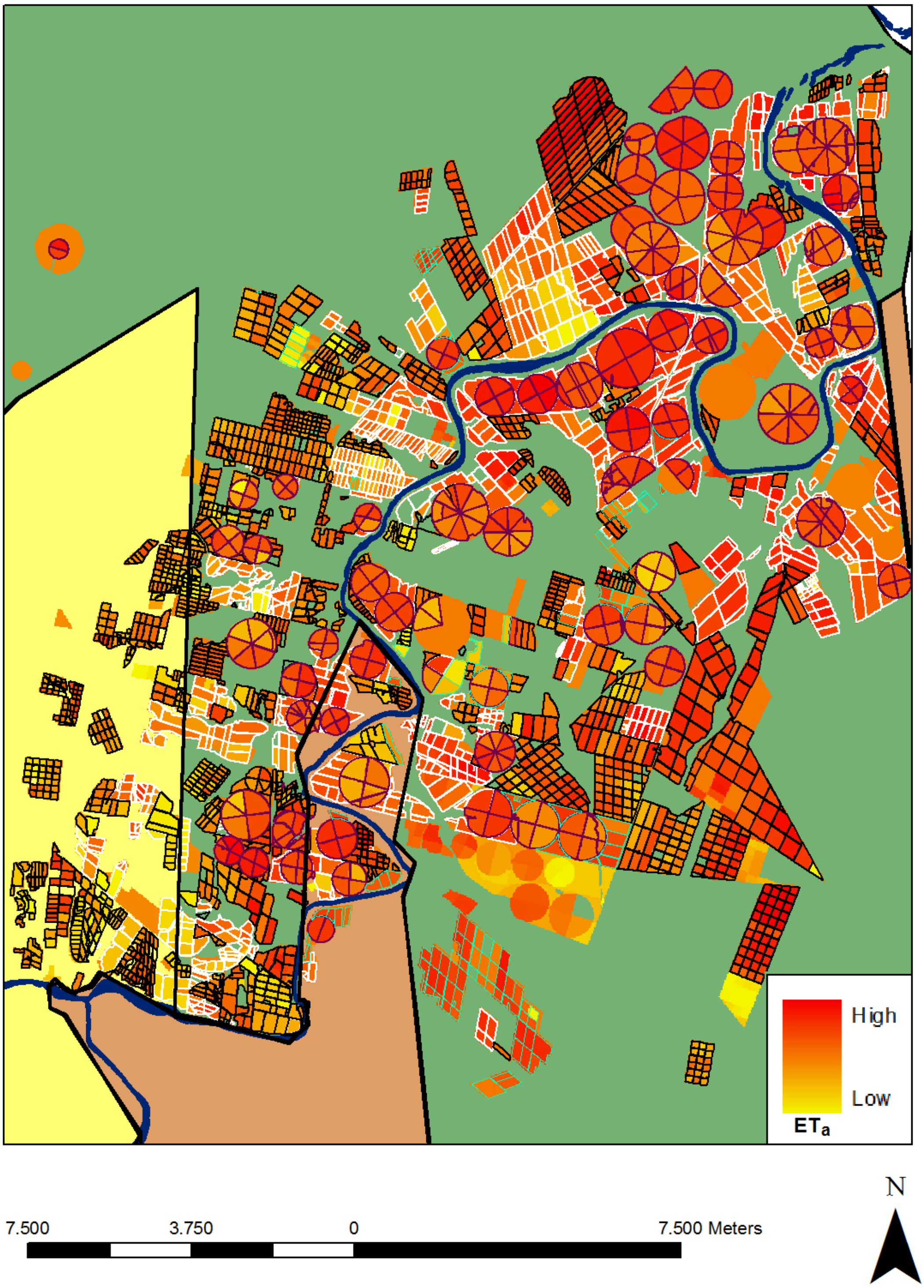
SOIL CLASS 3

BLACK OUTLINED:
FIELDS UNDER DRAG LINE IRRIGATION

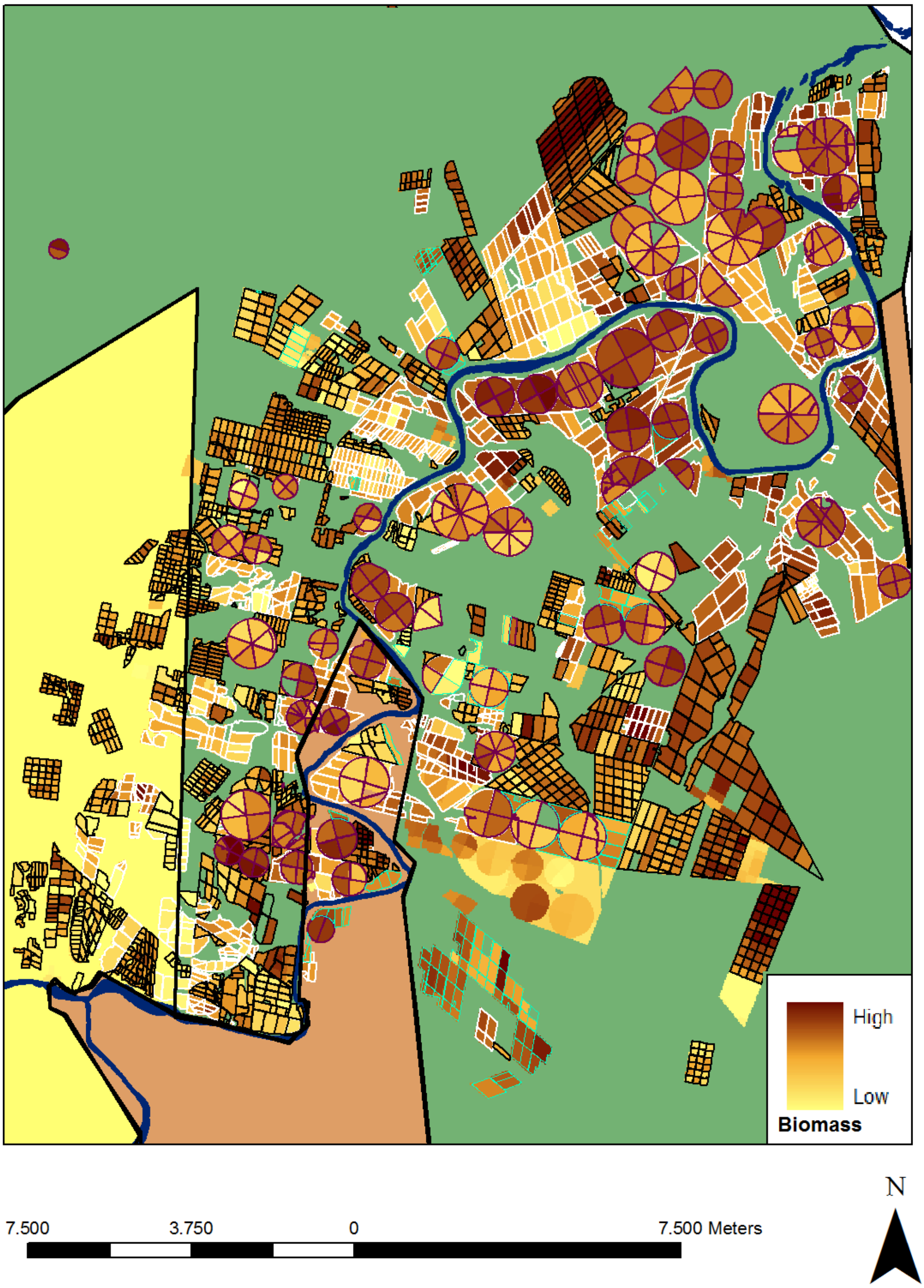
WHITE OUTLINED:
FIELDS UNDER FLOPPY IRRIGATION

PURPLE OUTLINED:
FIELDS UNDER PIVOT IRRIGATION

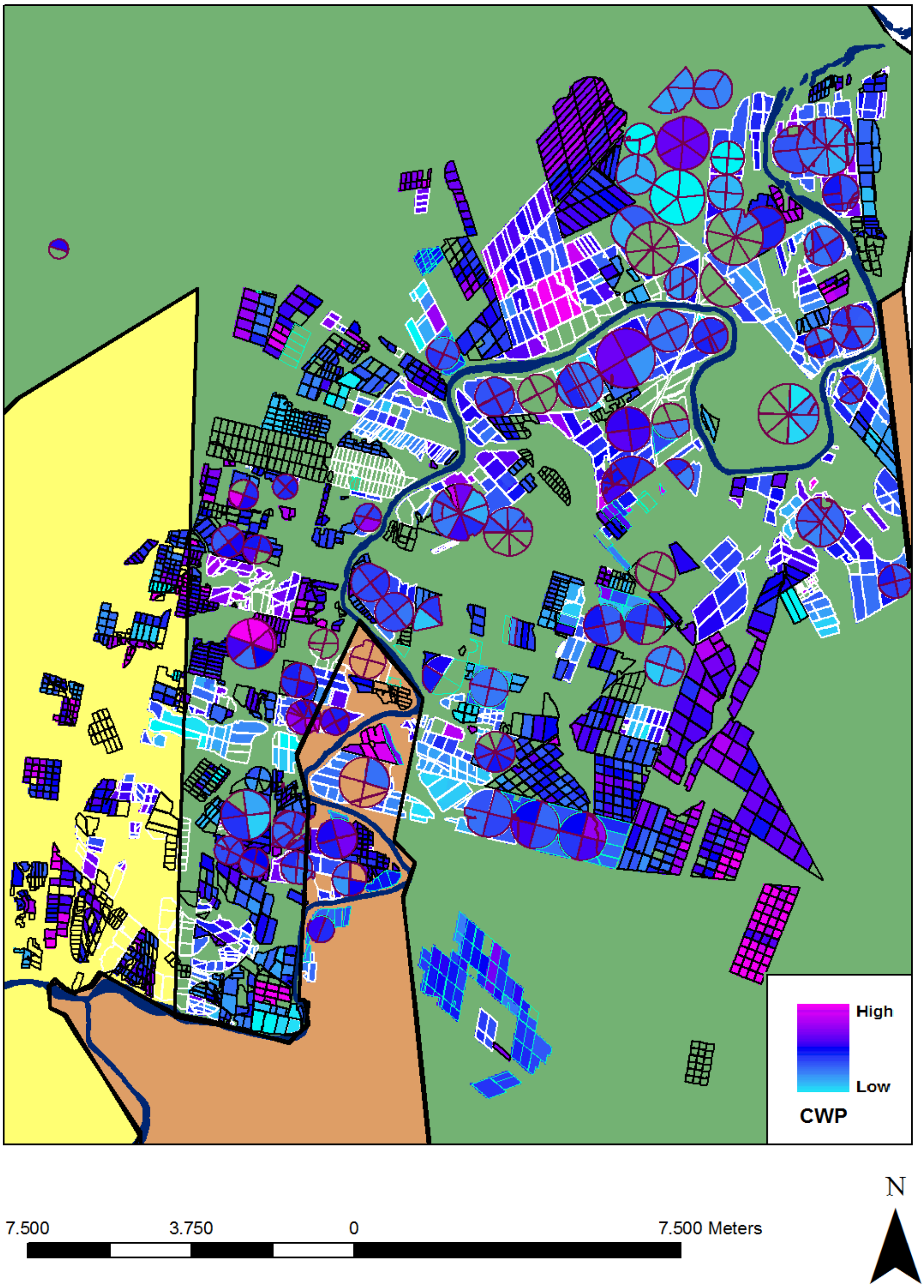
ANNEX IV - A



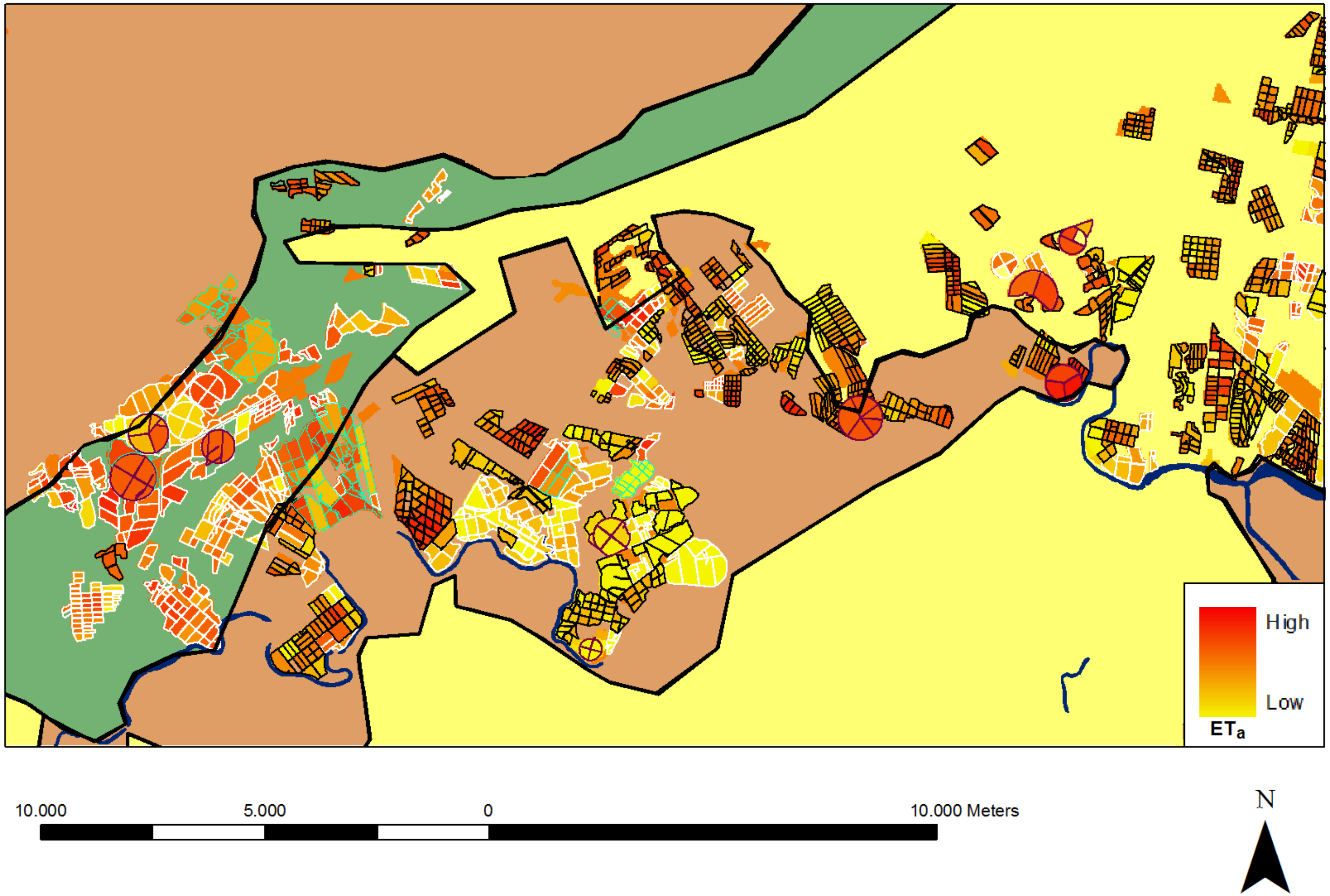
ANNEX IV - B



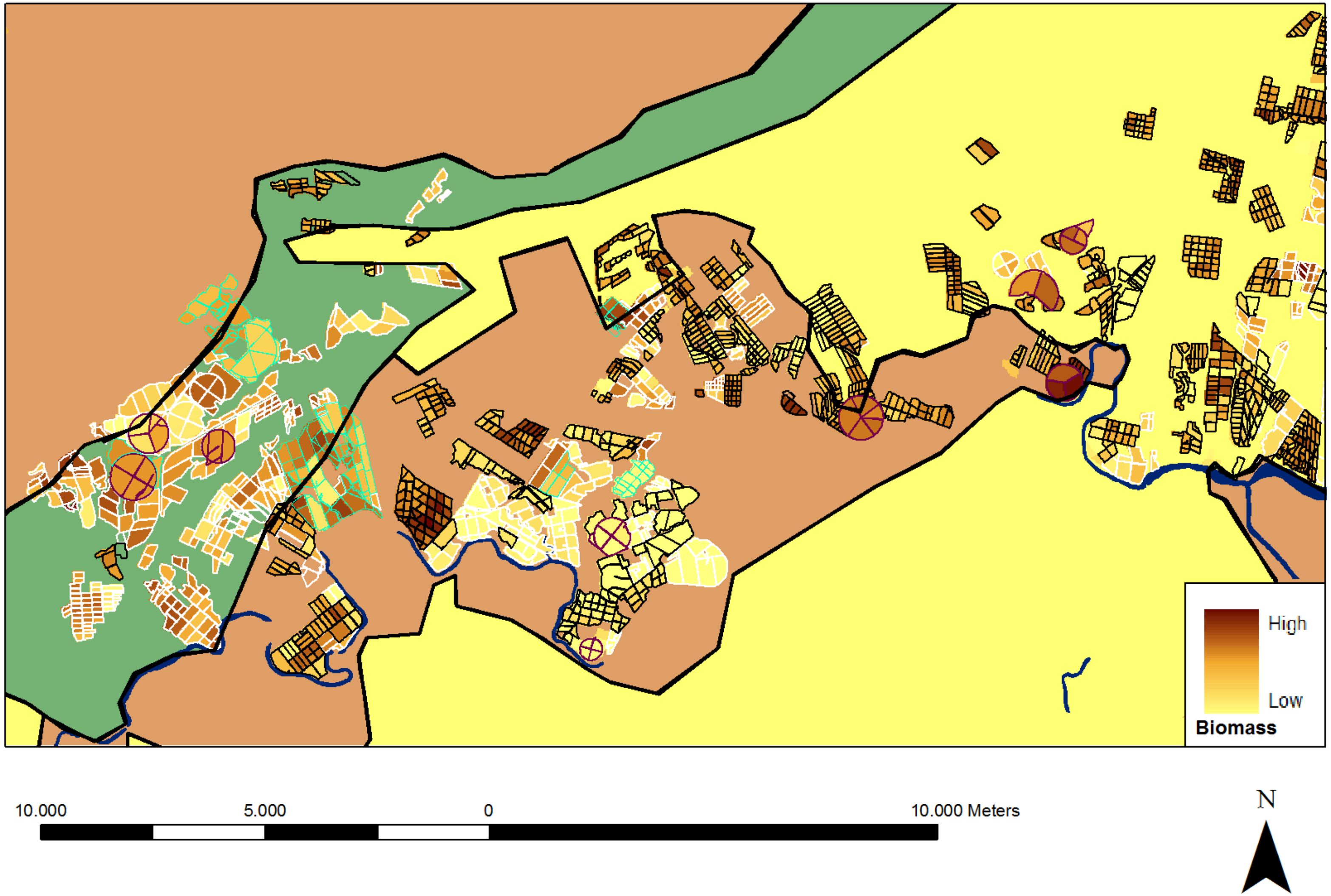
ANNEX IV - C



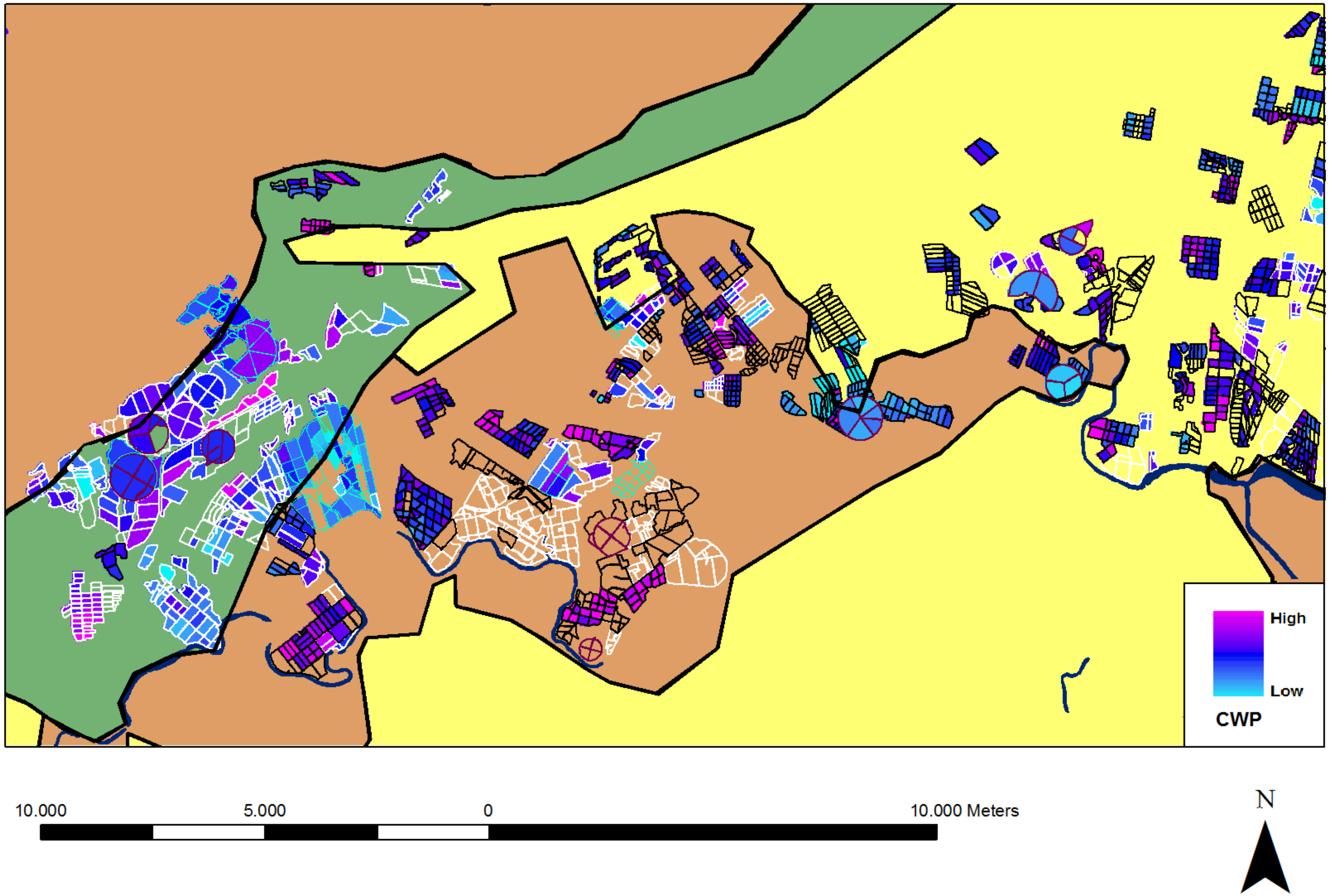
ANNEX IV - D



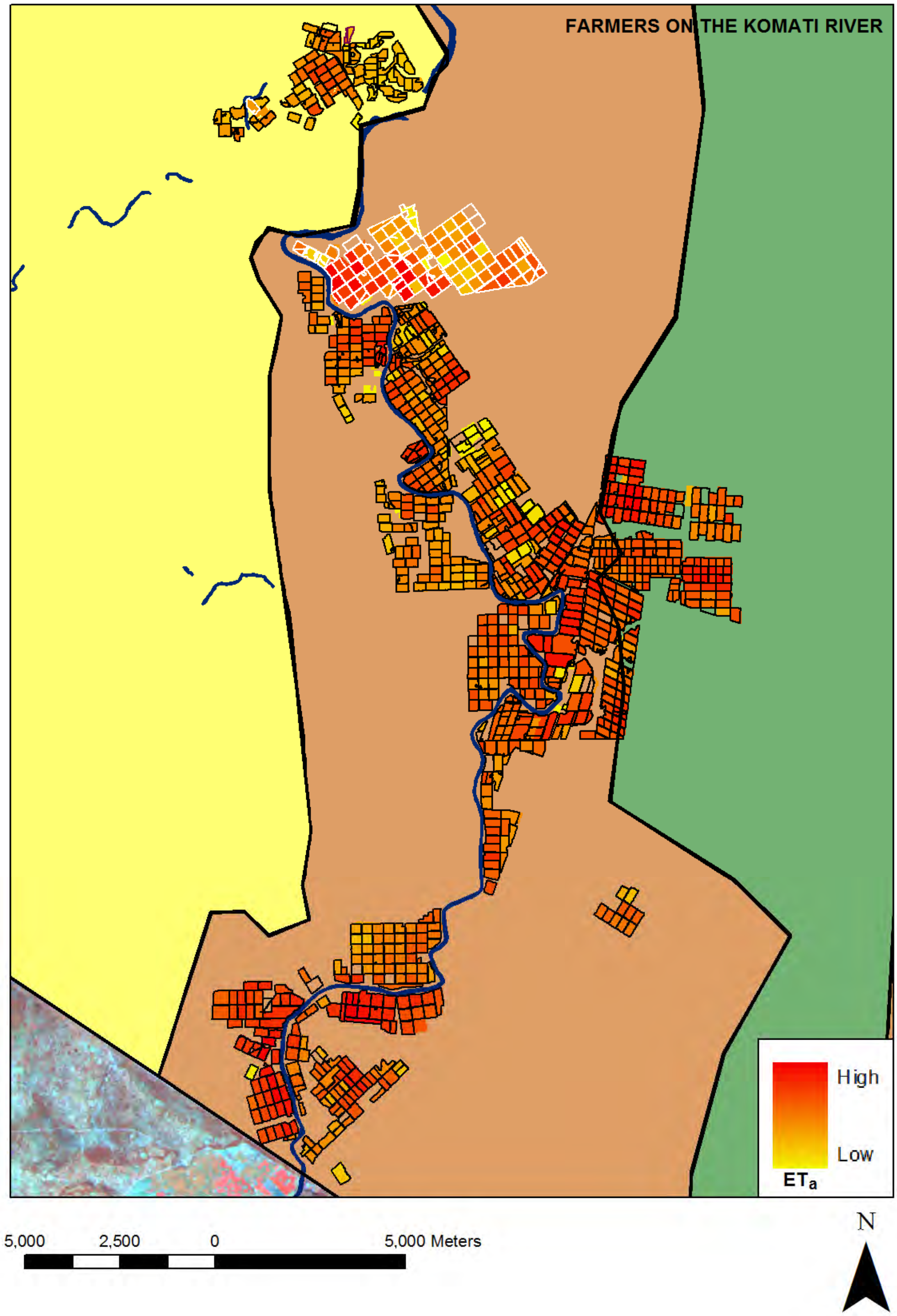
ANNEX IV - E



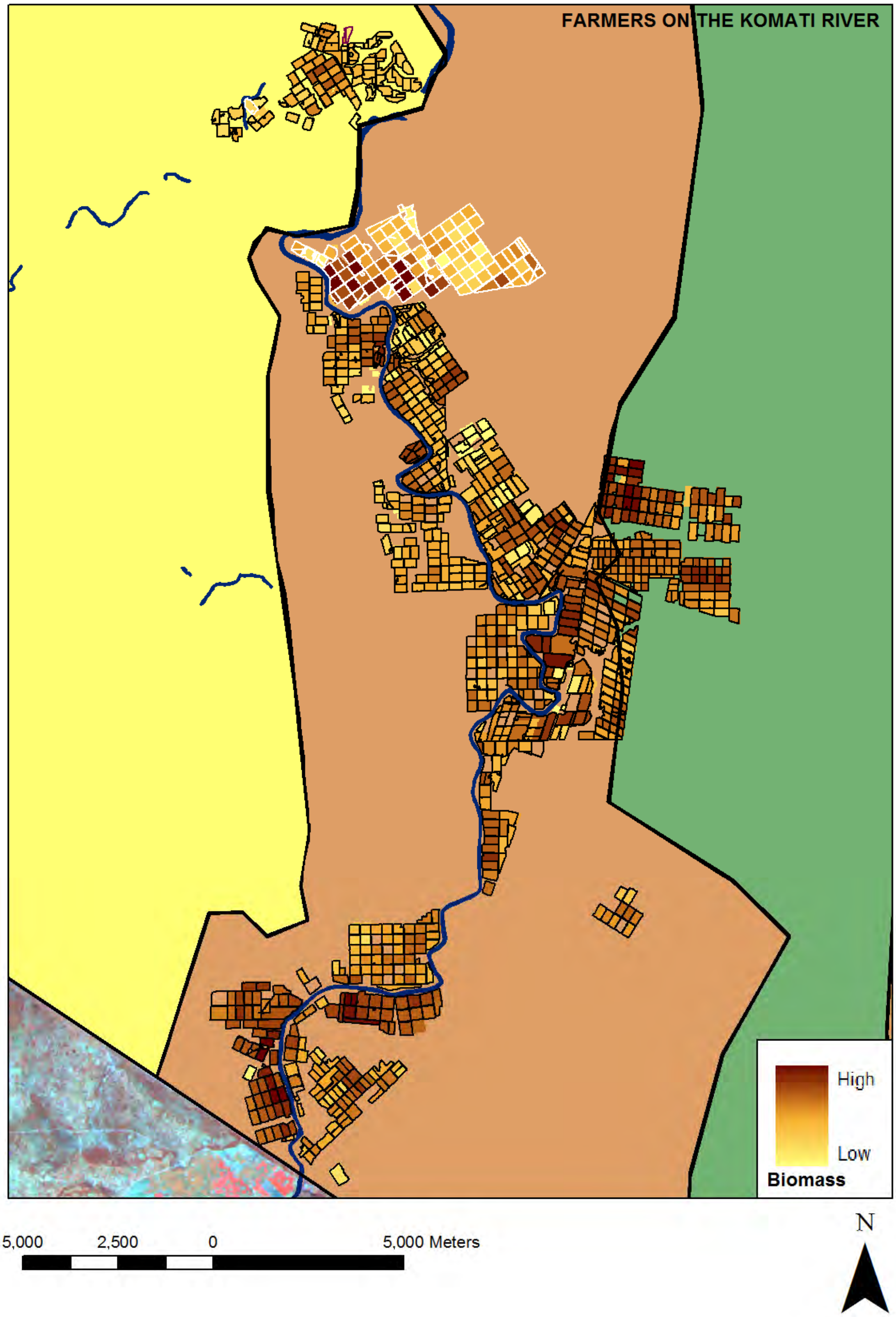
ANNEX IV - F



ANNEX V - A

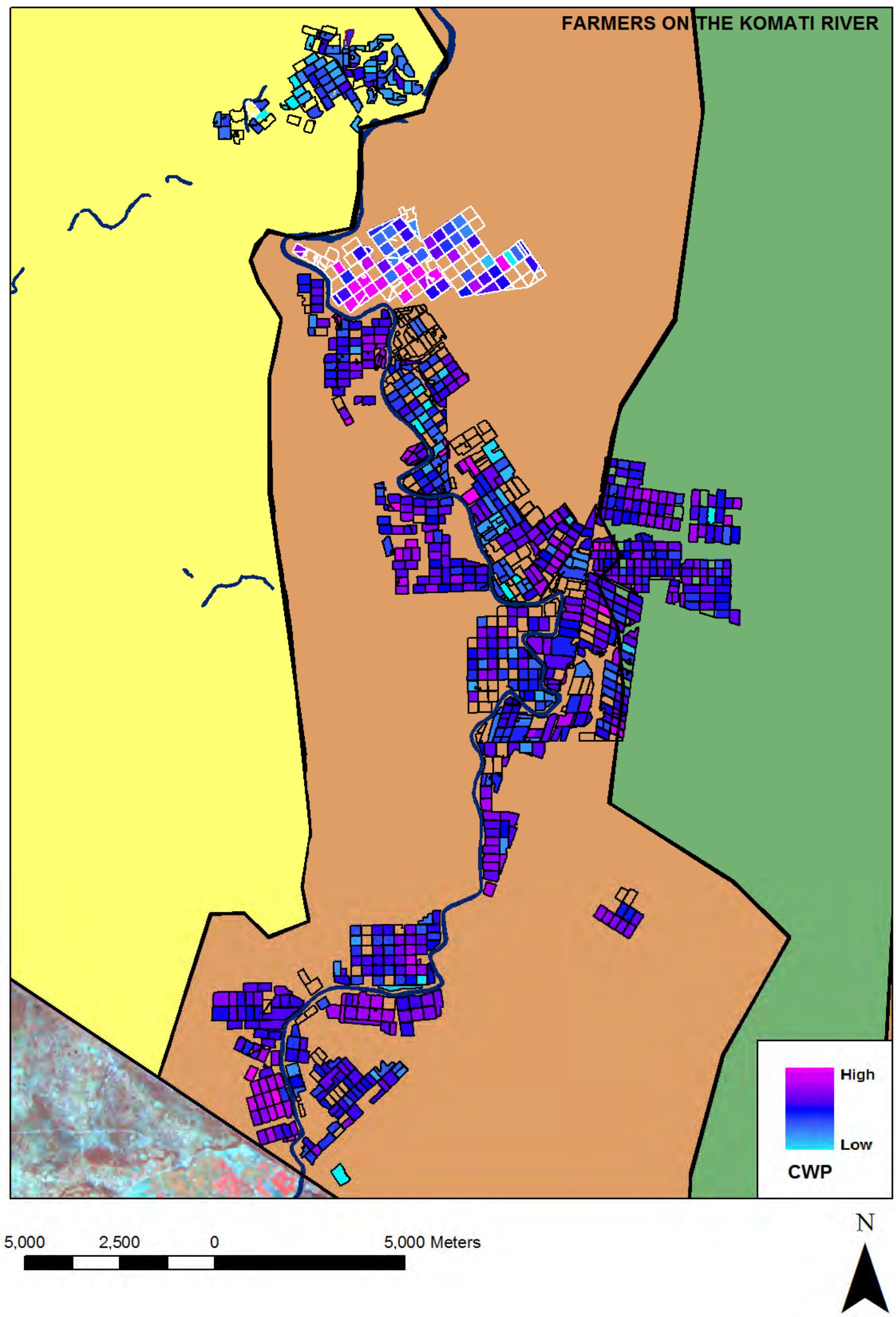

FARMERS ON THE KOMATI RIVER
High
Low
ET_a
5,000
2,500
0
5,000 Meters
N

ANNEX V - B

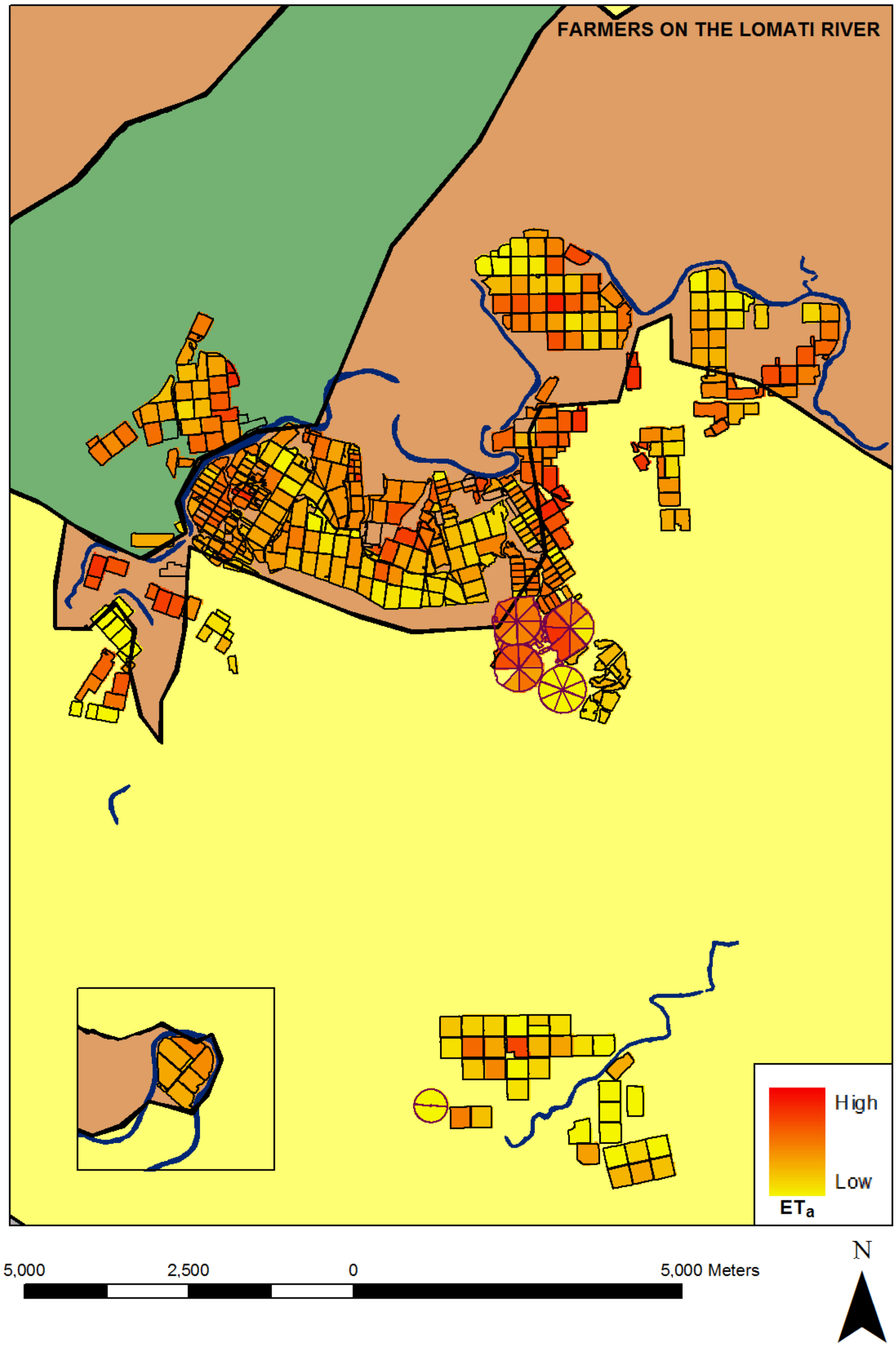


FARMERS ON THE KOMATI RIVER
High
Low
Biomass
5,000
2,500
0
5,000 Meters
N

ANNEX V - C

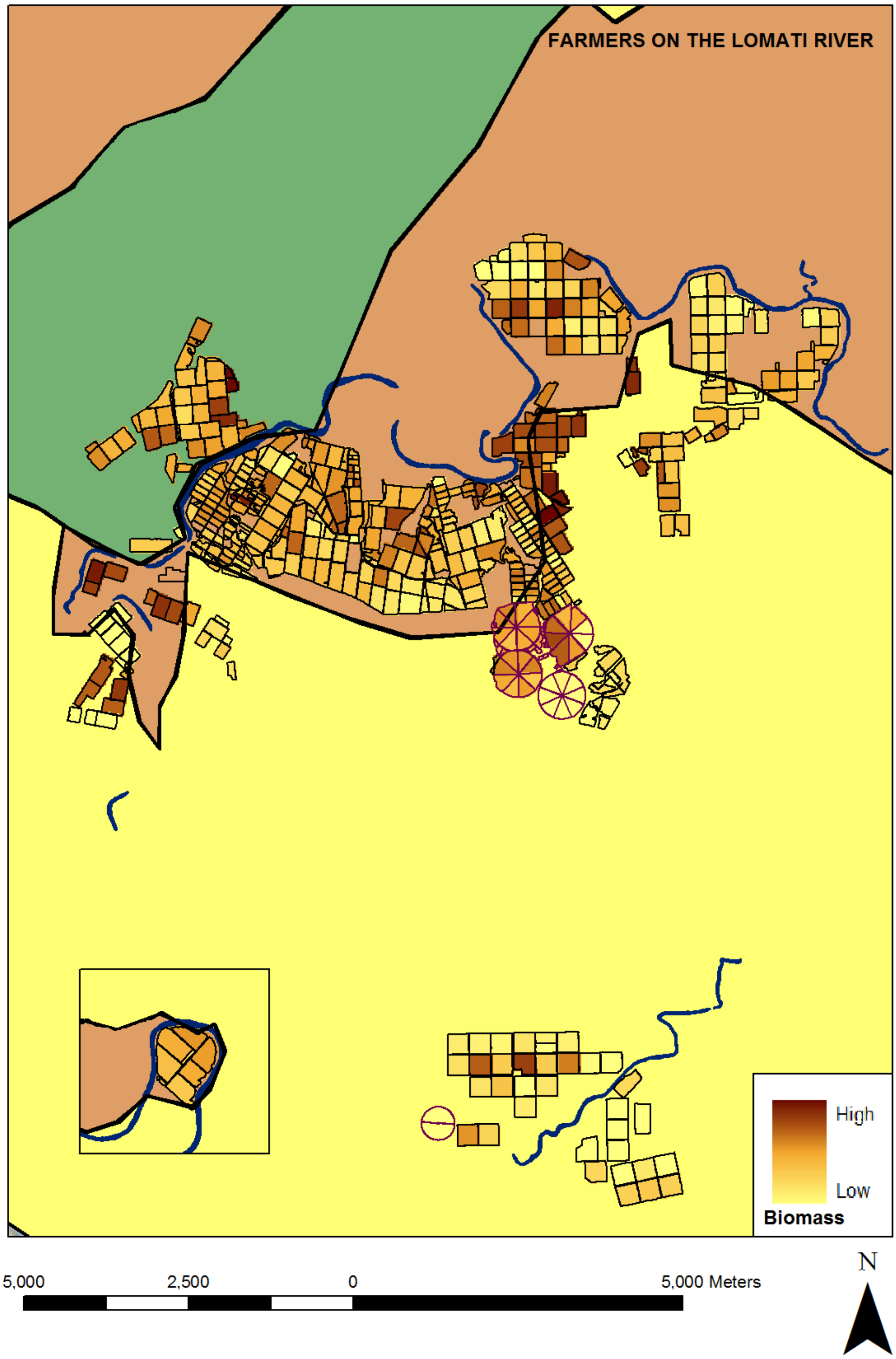

FARMERS ON THE KOMATI RIVER
High
Low
CWP
5,000
2,500
0
5,000 Meters
N

ANNEX V - D



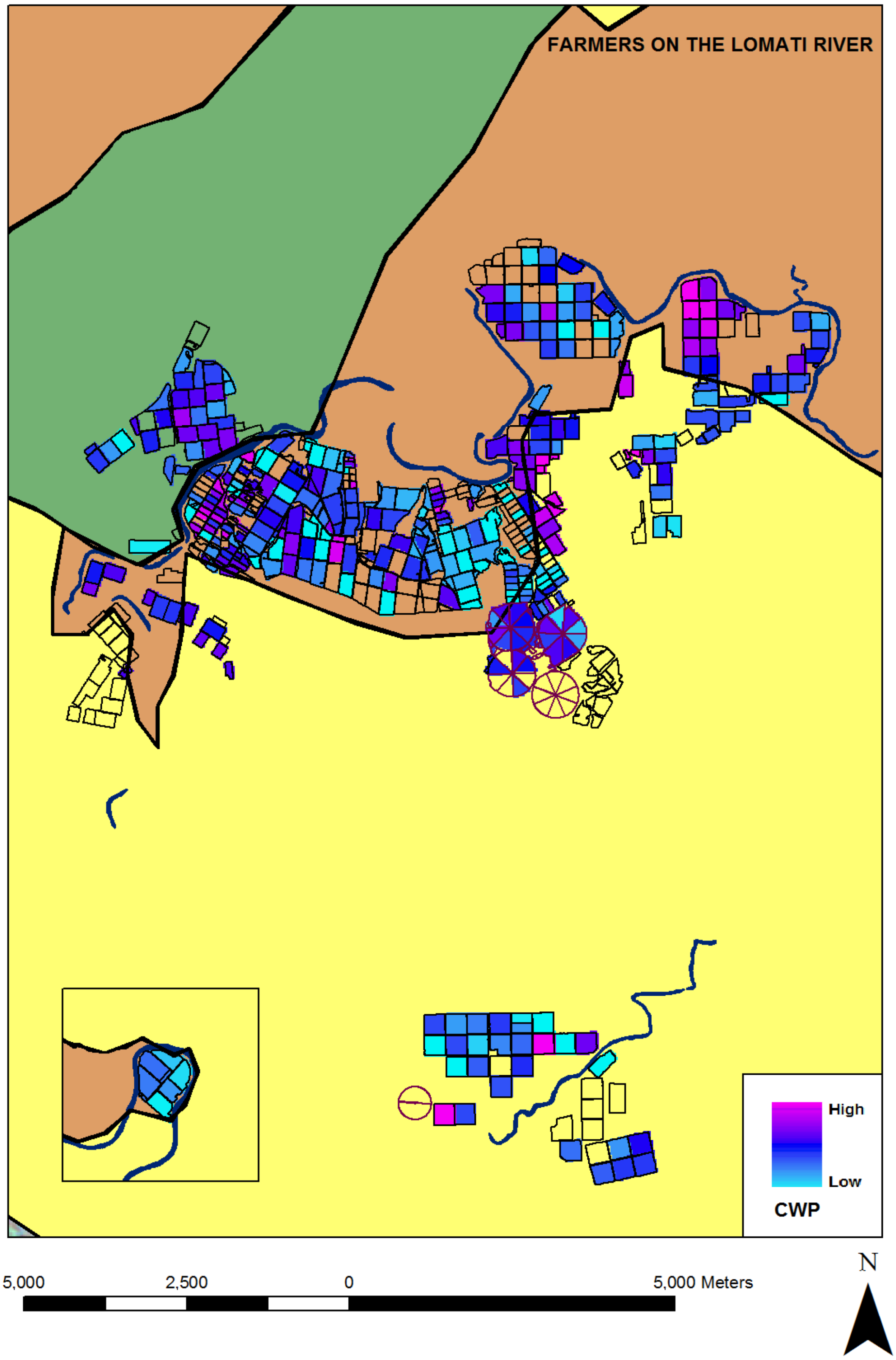
FARMERS ON THE LOMATI RIVER
High
Low
ET_a
5,000
2,500
0
5,000 Meters
N

ANNEX V - E



FARMERS ON THE LOMATI RIVER
High
Low
Biomass
5,000
2,500
0
5,000 Meters
N

ANNEX V - F


FARMERS ON THE LOMATI RIVER
High
Low
CWP
5,000
2,500
0
5,000 Meters
N

ANNEX VI - TECHNICAL ANNEX

Introduction to SEBAL

The Surface Energy Balance Algorithm for Land (SEBAL) was originally developed by WaterWatch (http://www.waterwatch.nl). SEBAL computes actual, potential and reference evapotranspiration, root zone soil moisture and biomass growth from low resolution (1000m) to high resolution (30m) satellite images.

SEBAL is an image-processing model with 25 computational steps that calculate the actual and potential evapotranspiration rates, as well as other energy exchanges between land and atmosphere. The key input data for SEBAL consists of spectral radiance in the visible, near-infrared and thermal infrared part of the spectrum. SEBAL computes a complete radiation and energy balance along with the resistances for momentum, heat, and water vapour transport for every individual pixel. These resistances are a function of state conditions such as soil water potential (and thus soil moisture), wind speed, and air temperature. They change from day-to-day.

The first step is to convert satellite radiances into land surface characteristics such as surface albedo, leaf area index, vegetation index and surface temperature. These land surface characteristics can be derived from different types of satellites. An instantaneous evapotranspiration is computed, which is then subsequently scaled up to 24-hours and longer periods.

In addition to satellite images, the SEBAL model requires the following routine weather data:

- wind speed
- humidity
- solar radiation
- air temperature

Data on land use, soil type or hydrological conditions are not required to apply SEBAL (WaterWatch, 2008). Due to my relatively short research period, a simplified SEBAL approach was used, focusing on relative rather than absolute values of ET and Biomass growth. All calculations were done for the Lower Komati sub-catchment.

SEBAL Evapotranspiration

The FAO Penman-Monteith equation (1) was used in determining the evapotranspiration from the hypothetical grass reference surface (ET_0). This method requires radiation, air temperature, air humidity and wind speed data, which were retrieved from a weather station in the research area. Calculation procedures to derive climatic parameters from meteorological data and to estimate missing meteorological variables required for calculating ET_0 are presented in FAO Irrigation and Drainage Paper 56 (FAO, 1998).

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \text{ (mm/day)} \qquad (1)$$

where ET_0 reference evapotranspiration [mm/day],
R_n net radiation at the crop surface [$MJ/m^2/day$],

G soil heat flux density [MJ/m^2/day],
T air temperature at 2 m height [°C],
u_2 wind speed at 2 m height [m/s],
e_s saturation vapour pressure [kPa],
e_a actual vapour pressure [kPa],
e_s-e_a saturation vapour pressure deficit [kPa],
Δ slope vapour pressure curve [kPa/°C],
γ psychrometric constant [kPa/°C].

The maximum crop evapotranspiration under standard conditions, ET_c, was then determined by using an experimentally determined crop coefficient (K_c=Et_c/ET_0) of 1.25 for a full grown sugarcane crop (FAO, 1998). ET_0 and ET_c were determined for 9 Landsat Thematic Mapper (TM) images (path 168 – row 78) ranging from May 30, 2004 to May 17, 2005.

Image	**Date**	**Year**	**ET_0 (mm/day)**	**K_c (-)**	**ET_c (mm/day)**
1	May 30	2004	2.89	1.25	3.61
2	Aug 10	2004	3.48	1.25	4.35
3	Sep 11	2004	4.12	1.25	5.15
4	Oct 29	2004	6.59	1.25	8.24
5	Nov 14	2004	5.51	1.25	6.89
6	Feb 18	2005	6.06	1.25	7.58
7	Mar 6	2005	5.14	1.25	6.43
8	Mar 30	2005	4.32	1.25	5.40
9	May 17	2005	2.69	1.25	3.37

Table 1: ET_0 and ET_c for the 9 images.

The calculated ET_c was then used in an "Unsupervised Classification of Surface Albedo, Surface Temperature, and NDVI" described by Pelgrum and Bastiaanssen (1996) to determine the area-averaged latent heat flux (ET) as a weighted average of ground-based observations. The weighting coefficients were obtained from remote sensing measurements. This method combined satellite images of surface temperature, surface albedo, and normalized difference vegetation index (NDVI) into an index on a pixel-by-pixel basis:

$$index = \frac{T_0}{T_{0,\max}} \left(\frac{r_0}{r_{0,\max}} \right)^{1/2} (1 - NDVI) \text{ (-)} \qquad (2)$$

where r_0,max and T_0,max are the maximum values of the surface albedo and surface temperature appearing on a particular image.

The albedo values for each satellite image were calculated using the method described by Tasumi *et al*. (2008) in which broadband surface albedo (α_s) was estimated by separately calculating at-surface reflectance (ρ_s) for each satellite sensor band (*b*) and then integrating these reflectances according to intensities of at-surface solar radiation (incoming) within the domain of the band:

$$\alpha_s = \sum_{b=1}^{6} \left[\rho_{s,b} \cdot w_b \right] \text{ (-)} \qquad (3)$$

where w_b is the weighting coefficient representing the fraction of at-surface solar radiation occurring within the spectral range represented by a specific band. This method was developed for use with high-resolution (30m) Landsat images, and utilizes Landsat TM bands 1-5 and 7. Areamasks and cloudmasks were applied to all images in order to focus on agricultural areas only and filter out the unwanted areas such as clouds, water and forestry.

The NDVI values for each image were calculated using a simple formula utilizing the red (R) and near infra red (NIR) bands (Clevers *et al*., 2006).

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \text{ (-)} \qquad (4)$$

The earth surface temperature ($T_{surface}$) for each image was then computed from the satellite measurements of thermal radiances, using the thermal infrared surface emissivity (ε). This method utilizes the thermal band of Landsat TM (band 6). The method described by Wukelic *et al*. (1989) was used to convert the Landsat images into long wave radiation and to calculate the effective at-satellite temperature ($T_{satellite}$) while the method described by Van De Griend and Owe (1993) was used to determine the thermal infrared surface emissivity of each image from the NDVI. The earth surface temperature was computed according to the Stefan-Boltzmann law which expresses that the rate of long wave emission is proportional to the absolute temperature of the surface raised to the fourth power (Becker, 1987):

$$T_{surface} = \frac{T_{satellite}}{\varepsilon^{1/4}} \text{ (°C)} \qquad (5)$$

After inclusion of these ground-based measurements and calculating the index on a pixel-by-pixel basis for each individual image, the index was plotted against the ET_c for each of the 9 images. It was assumed that the maximum value of ET_c (with K_c=1.25 for a full grown sugarcane crop) related to the minimum value (2%) of the index, and that the minimum value of ET_c (zero) related to the maximum value (98%) of the index. In this way, pixels with a high maximum NDVI, a low albedo, and a low surface temperature were linked to pixels with maximum ET and minimum index values. Pixels with the highest ET were thus used as a maximum value in order to scale the rest of the pixels according to the index.

Image	Date	Year	$ET_{c,max}$ (mm/day)	$Index_{min}$ (2%) (-)	$ET_{c,min}$ (mm/day)	$Index_{max}$ (98%) (-)
1	May 30	2004	3.61	0.070	0	0.261
2	Aug 10	2004	4.35	0.080	0	0.401
3	Sep 11	2004	5.15	0.112	0	0.431
4	Oct 29	2004	8.24	0.117	0	0.460
5	Nov 14	2004	6.89	0.135	0	0.469
6	**Feb 18**	**2005**	**7.58**	**0.068**	**0**	**0.355**
7	Mar 6	2005	6.43	0.064	0	0.453
8	Mar 30	2005	5.40	0.043	0	0.233
9	May 17	2005	3.37	0.041	0	0.189

Table 2: Maximum and minimum ET_c and index values for the 9 images.

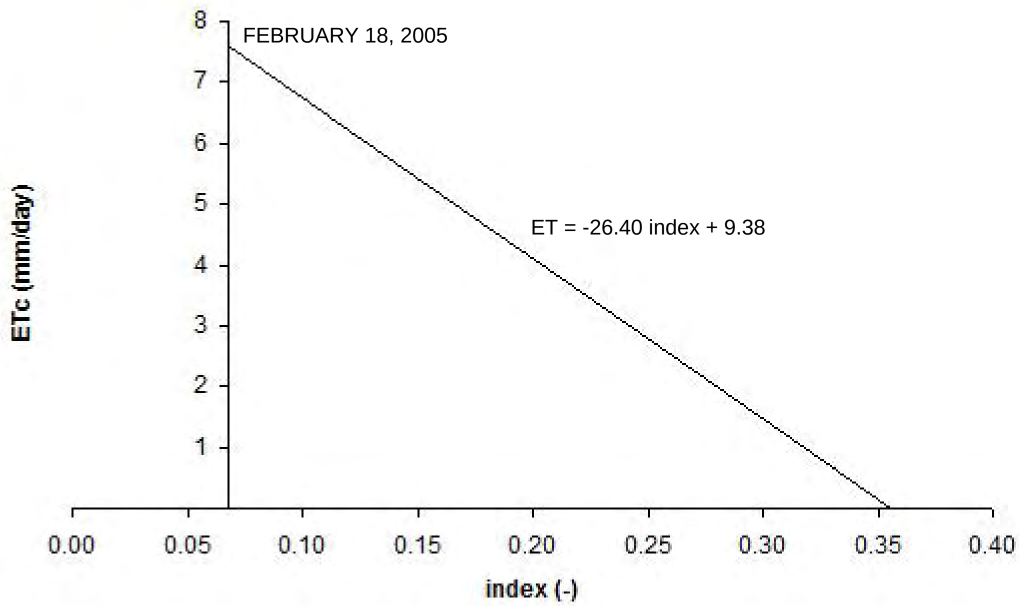


Figure 1: Plotting the index against the ET_c in order to establish a linear relationship between the index and the latent heat flux (February 18, 2005 is taken as example).

A linear relationship was established between the index and the latent heat flux ($ET = a \cdot index + b$). This relationship was used to map the latent heat flux (ET) on a pixel-by-pixel basis for each image (figure 2a). In order to get an average ET value for each individual field (as opposed to an ET value for each individual pixel) a Zonal Mean Function was carried out in Erdas Imagine using a grid with the outlines of each sugarcane field as additional input (figure 2b). This resulted in an output image showing an average ET per field (figure 2c).

The locations of the sugarcane fields were obtained by using a DWAF Land Use Map, GIS-data provided by TSB, and my own interpretations from Google Earth. Calculations were performed on sugarcane fields only, excluding other agricultural fields (e.g. bananas, citrus) and forestry.

After estimating the average ET per sugarcane field for each of the 9 images, the sum of the ET for sugarcane for the 2004/2005 season (May 30, 2004 – May 17, 2005) was calculated for each individual sugarcane field. This was done by plotting the ET (mm/day) against the time (days), and then calculating the area under the graph. This resulted in a final image showing the averaged total sum ET for the 2004/2005 season for each individual sugarcane field (figure 4).

N.B.
It must be noted that only 9 images were used for analysis. These images were taken on cloud free days or days with minimal cloud cover. As linear interpolation over time was used to calculate the total ET over the 2004/2005 season, there is a good possibility that the calculated values for ET are overestimating the actual values for ET. This is because the ET over cloudy periods is most likely less than the interpolated ET. However, as this research focuses on relative differences between sugarcane plots this is not a major limitation for this thesis.

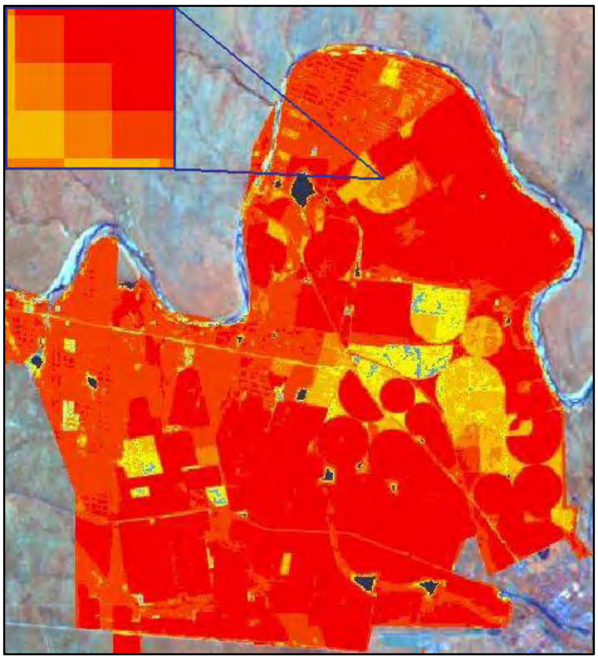


Figure 2a: Each pixel in the image has its own ET value.

Figure 2b: The outlines of each individual sugar - cane field.

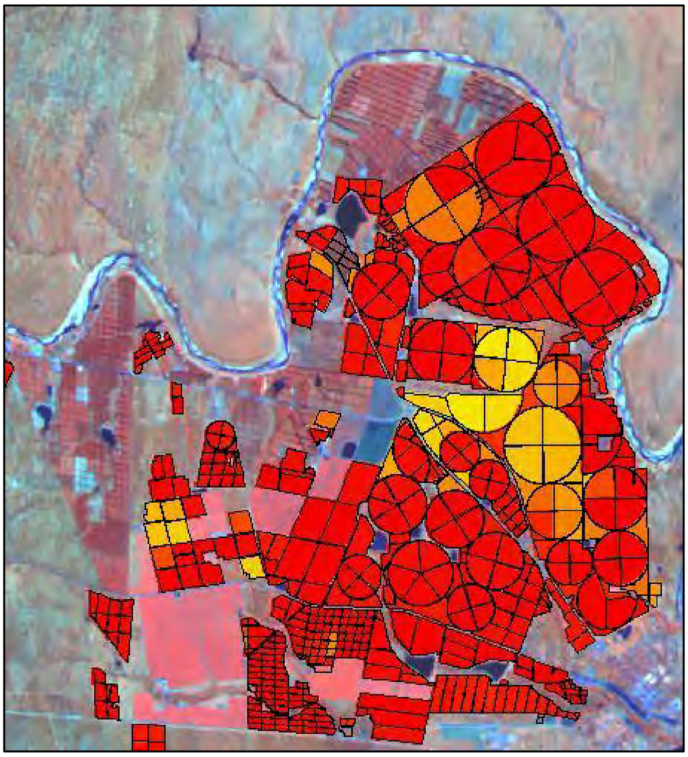


Figure 2c: Each sugarcane field has its own averaged ET value.

Figure 2: A subset image of the satellite image of May 30, 2005 is taken as example. It shows the ET values for each individual pixel (figure 2a), the outlines of the sugarcane fields (figure 2b), and the averaged ET values per field (figure 2c). The red colours correspond to high ET values while the yellow colours correspond to low ET values.

Figure 3: The area under the graph is the averaged total sum ET for the 2004/2005 season for a sugarcane field. This example shows a field with maximum ET values.

Date	Day	ET
May 30, 2004	1	3.61
Aug 10, 2004	73	4.35
Sep 11, 2004	105	5.15
Oct 29, 2004	153	8.24
Nov 14, 2004	169	6.89
Feb 18, 2005	266	7.58
Mar 6, 2005	283	6.43
Mar 30, 2005	307	5.40
May 17, 2005	355	3.37

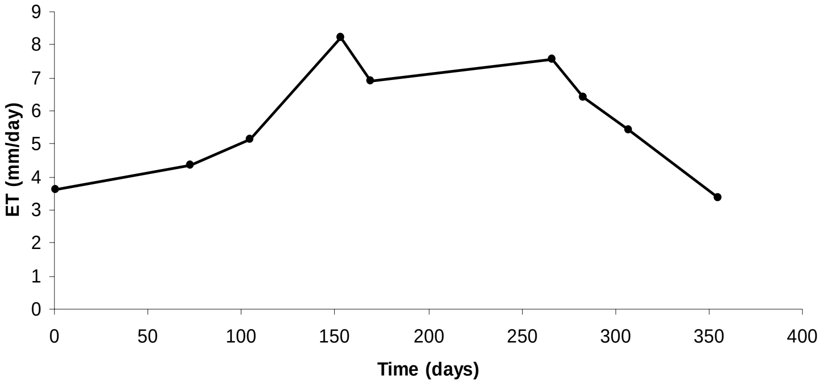


Figure 4: A subset image showing the total averaged ET of individual sugarcane fields for the 2004/2005 season. The red colours correspond to high ET values while the yellow colours correspond to low ET values.

SEBAL Biomass growth

The biomass production routine in SEBAL is based on solar radiation absorption by chlorophyll and the conversion of this energy into a dry matter production by means of a light use efficiency (Bastiaanssen & Ali, 2003):

$$Bio_{act}^{tot} = \varepsilon\Sigma(APAR(t)t) \text{ (kg/ha)} \quad (6)$$

The absorption of solar radiation (APAR) for photosynthesis depends on global radiation and light interception. ε describes the light use efficiency that converts energy into dry matter and *t* describes the period over which accumulation takes place.

Photosynthetic Active Radiation (PAR) (0.4 to 0.7 µm) is part of the short wave solar radiation (0.3 to 3.0 µm) that is absorbed by chlorophyll for photosynthesis in the plants. PAR is thus a fraction of the incoming solar radiation $K^{\downarrow}$. The PAR/ $K^{\downarrow}$ fraction varies with visibility, optical depth and ozone amount, but a value of 45-50% is generally accepted to represent the 24h average conditions (Bastiaanssen & Ali, 2003):

$$PAR = 0.48K_{24}^{\downarrow} \text{ (W/m}^2\text{)} \quad (7)$$

The PAR was obtained using data from meteorological stations on the daily maximum hours of sunshine, *N (t)*, and the actual number of hours having direct sunshine exposure, *n (t)*. $K_{24}^{\downarrow exo}(t)$ was calculated using the formula for extraterrestrial radiation R_a as described in the FAO Irrigation and Drainage Paper No. 56 (FAO, 1998).

$$K_{24}^{\downarrow}(t) = \left\{0.25 + \frac{0.50n(t)}{N(t)}\right\} K_{24}^{\downarrow exo}(t) \text{ (MJ/m}^2\text{/day)} \quad (8)$$

$$K_{24}^{\downarrow exo} = R_a = \frac{24(60)}{\pi} G_{sc} d_r \left[\omega_s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s)\right] \text{ (MJ/m}^2\text{/day)} (6)$$

where

where	R_a	extraterrestrial radiation [MJ/m^2/day]
	G_{sc}	solar constant = 0.0820 MJ/m^2/min
	d_r	inverse relative distance Earth-Sun
	ω_s	sunset hour angle [rad]
	φ	latitude [rad]
	δ	solar declination [rad]

The PAR value describes the total amount of radiation available for photosynthesis if leaves intercept all radiation. This is a rather theoretical value, because leaves transmit and reflect solar radiation. Only a fraction of PAR will be absorbed by the canopy (APAR) and used for carbon assimilation. APAR can be approximated as a fraction of the PAR using the Normalized Difference Vegetation Index (NDVI):

$$APAR = (-0.161 + 1.275\ NDVI) * PAR \text{ (W/m}^2\text{)} \quad (9)$$

The light use efficiency ε was calculated using the method developed by Field *et al*. (1995, as cited in Wim & Bastiaanssen, 2003):

$$\varepsilon = \varepsilon' T_1 T_2 W \text{ (g/MJ)} \quad (10)$$

$$W = \frac{ET}{R_n - G_0} \text{ (-)} \quad (11)$$

$$T_1 = 0.8 + 0.02T_{opt} - 0.0005T_{opt}^2 \text{ (°C)} \quad (12)$$

$$T_2 = \frac{1}{1+\exp(0.2T_{opt} - 10 - T_{mon})} \cdot \frac{1}{1+\exp\{0.3(-T_{opt} - 10 + T_{mon})\}} \text{ (°C)} \quad (13)$$

ε' is a typical maximum conversion factor for above ground biomass when the environmental conditions are optimal. In this study a value of 4.0 g/MJ is used for ε' (Bastiaanssen & Ali, 2003). W is the evaporative fraction of the surface energy balance, ET the latent heat flux, R_n the net radiation and G_0 the soil heat flux. T_{opt} (°C) is the mean air temperature during the month of maximum leaf area index or NDVI development, and T_{mon} (°C) is the mean monthly air temperature.

Doing these calculations resulted in a mapping of biomass (kg/ha) on a pixel-by-pixel basis for each image (figure 5a). Using the same procedure as before, the average biomass per sugarcane field was calculated using the Zonal Mean Function in Erdas Imagine. This resulted in an output image showing the average biomass per field (figure 5b).

Figure 5a: Each pixel in the image has its own biomass value.

Figure 5b: Each sugarcane field has its own averaged biomass value.

Figure 5: A subset image of the satellite image of May 30, 2005 is taken as example. It shows the biomass values for each individual pixel (figure 5a), and the averaged biomass values per sugarcane field (figure 5b). The dark colours correspond to high biomass values while the light colours correspond to low biomass values.

As the biomass was calculated over certain intervals (the amount of days between the dates the satellite images were taken) the total sum of the biomass of sugarcane for the 2004/2005 season (May 30, 2004 – May 17, 2005) was calculated by simply adding the biomass values of the nine images. This resulted in a final output image (figure 6).

The SEBAL model formulation for crop growth is on large tracks similar to most numerical crop growth simulation models and global scale ecological production models. A significant difference, though, is that crop development due to soil type, prevailing water management conditions and farmer practices is not computed, but prescribed through satellite measured NDVI and temperature time profiles (WaterWatch, 2008).

Figure 6: A subset image showing the total biomass of individual sugarcane fields for the 2004/2005 season. The dark colours correspond to high biomass values while the light colours correspond to low biomass values.

Crop Yield

The conversion of total above ground biomass development B_{act}^{tot} into crop yield Y_{act} uses crop parameters obtained from international literature. h_{ind} is the harvest index of sugarcane (0.69 kg/kg) and m_{oi} is the water content of sugarcane during harvest (0.65 kg/kg) (Bastiaanssen & Ali, 2003):

$$Y_{act} = \frac{h_{ind} B_{act}^{tot}}{1 - m_{oi}} \text{ (kg/m}^2\text{)} \qquad (14)$$

Applying equation (12) to the image of total biomass per sugarcane field for the 2004/2005 season (figure 6), resulted in an output image of the total actual yield for each sugarcane field for the 2004/2005 season (figure 7a). Having calculated the actual yield of sugarcane for the 2004/2005 from satellite images, these values were then compared to the actual yield values provided by TSB (figure 7b).

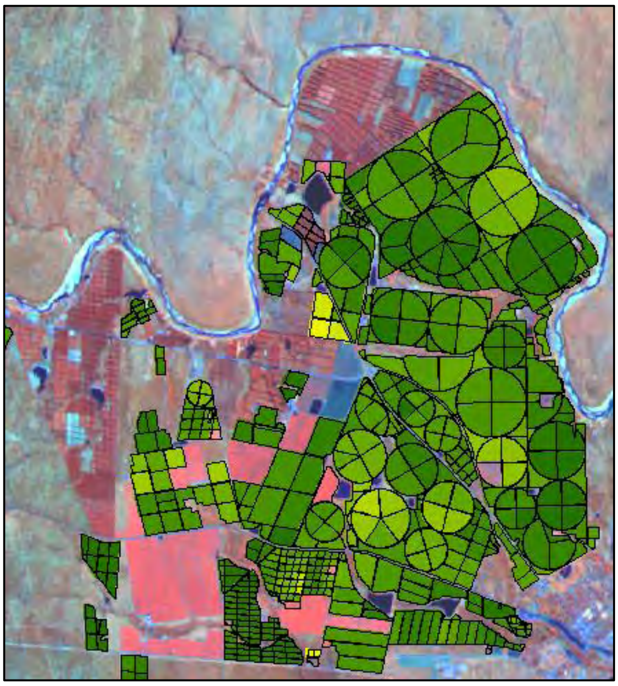


Figure 7a: Yield values calculated from satellite images.

Figure 7b: Yield values from the TSB database.

Figure 7: These subset images show the total yield of individual sugarcane fields for the 2004/2005 season calculated from satellite images (figure 7a) and obtained from the TSB database (figure 7b). The green colours correspond to high yield values while the yellow colours correspond to low yield values.

When comparing figure 7a to figure 7b it is clear that the yield values calculated using satellite images are higher than the actual yield values measured by TSB. However, when comparing the values of each field in Erdas Imagine using a Zonal Mean Model, and then plotting the values in Excel, there does seem to be a correlation between the calculated and the measured values. Fields with high calculated values correlate to fields with high measured values and vice versa (figure 8).

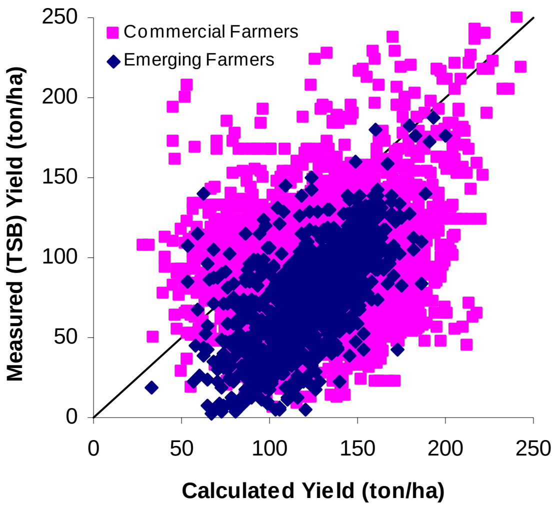


Figure 8: Correlation between the actual yield calculated from satellite images and the yield measured by TSB.

When it comes to the relation between yield and ET, which is generally acknowledged to be linear (De Wit, 1958), figures 9 to 11 show that this relationship holds true for the calculated yield, but shows variation when it comes to TSB measured yield.

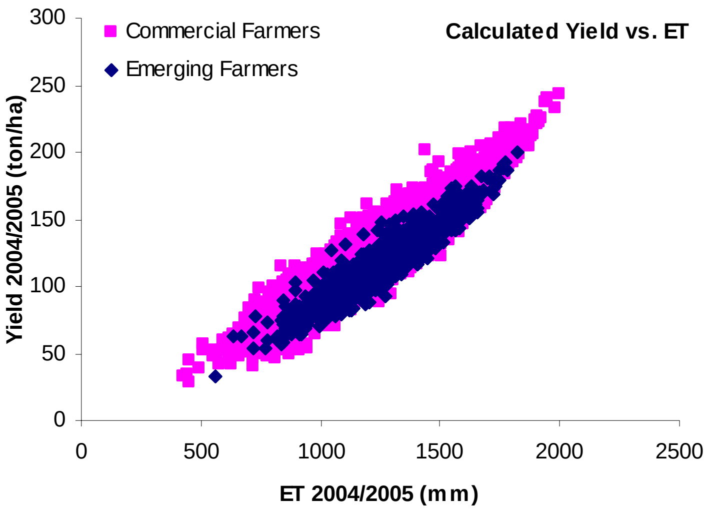


Figure 9: The linear relationship between calculated yield and ET.

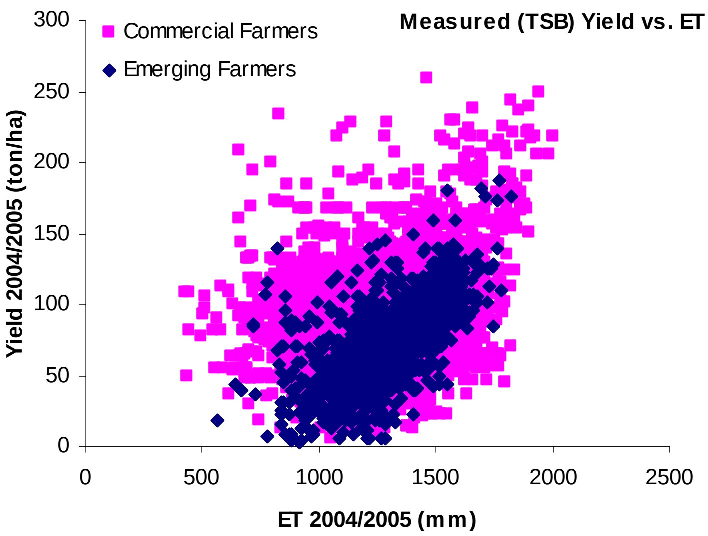


Figure 10: The relationship between the measured (TSB) yield and the ET.

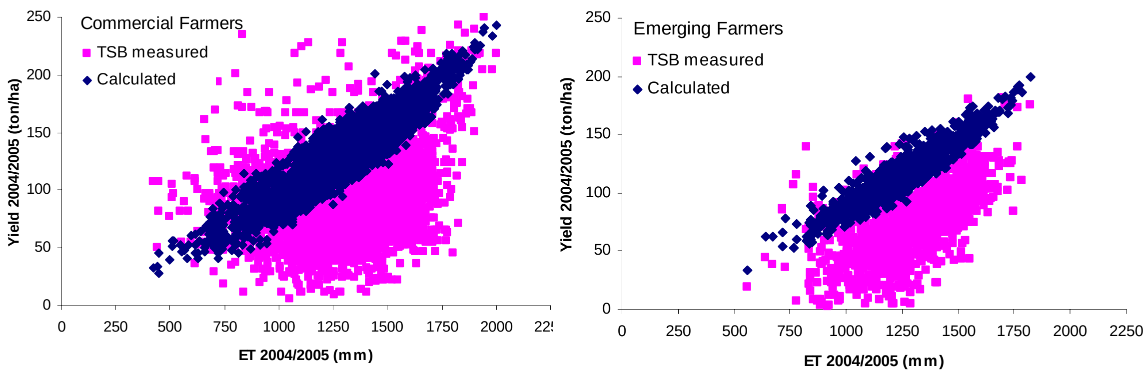


Figure 11: The relationship between calculated and measured (TSB) yield for commercial farmers (left) and the relationship between calculated and measured (TSB) yield for emerging farmers (right).

The procedure described above shows that satellite images are great tools for predicting crop yield. However, an accurate predication for crop yield requires more fine-tuning. It must be noted that the yield as calculated above does not take into account the age of the crop. As the harvesting season lasts from May to December, each field has its own harvesting date. Knowing the age of the crop allows for a more precise estimation of the biomass, and thus yield, for dates that were not captured by satellite images. Moreover, the values taken for the harvest index and the water content of sugarcane were taken from literature. These values may differ per plot. Therefore, the yield as calculated from the biomass may not be 100% correct.

Crop Water Productivity

The crop water productivity (CWP) is the crop yield (Y_{act}) per unit consumed water (ET) (Bos *et al*., 2005):

$$CWP = \frac{Y_{act}}{ET} \text{ (kg/m}^3\text{)} \qquad (15)$$

The CWP was calculated using the TSB measured yield which was provided by TSB in GIS format, and the ET as calculated from the satellite images. The TSB measured yield was used as this concerns the true, absolute, yield values for the 2004/2005 season, and would give a more accurate overview of CWP, than when using the calculated yield values. Calculating the CWP resulted in an image showing the CWP per individual sugarcane field for the 2004/2005 season (figure 9).

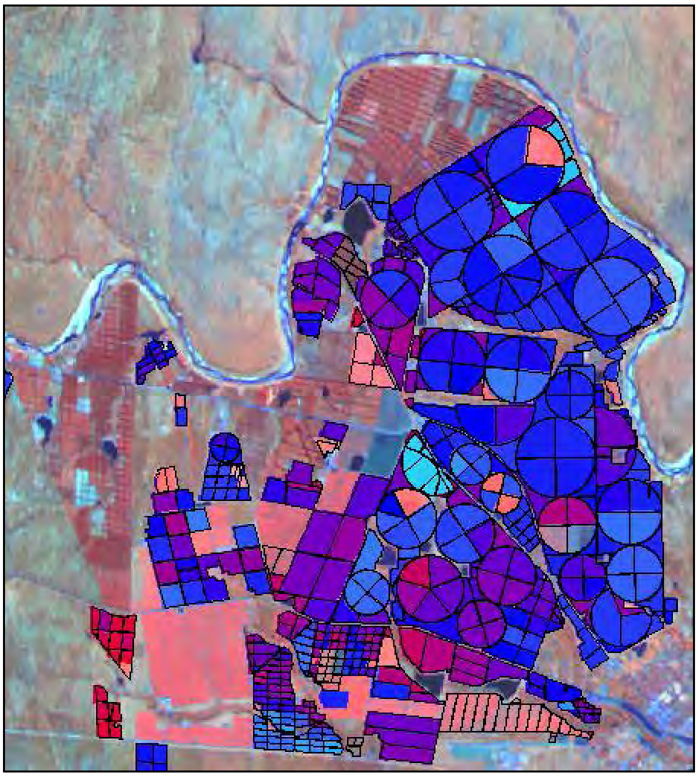


Figure 9: This subset image shows the crop water productivity of individual sugarcane fields for the 2004/2005 season. CWP values go from low (light blue) to medium (dark blue – purple) to high (pink).

This technical annex has shown the calculation procedures for, firstly, the evapotranspiration (ET) and the biomass growth, and secondly, the yield and the crop water productivity of sugarcane for the 2004/2005 season. The ET, Yield and CWP were the final outputs used as indicators for social-economic development in the research area.

REFERENCES

Bastiaanssen, W.G.M. & Ali, S (2003). A new crop yield forecasting model based on satellite measurements applied across the Indus Basin, Pakistan. *Agriculture, Ecosystems and Environment* 94: 321-340.

Becker, F. (1987). The impact of spectral emissivity on the measurement of land surface temperature from a satellite. *International Journal of Remote Sensing*. Vol. 8, Issue 10.

Bos, M.G., Burton, M.A. and Molden D.J., (2005). *Irrigation and drainage performance assessment, Practical Guidelines*. Wallingford. Oxfordshire, UK.

Clevers, J.G.P.W., Kooistra, L., Schaepman, M.E., Wit, A.J.W. de., Roerink, G.J. & Bartholomeus, H.M. (2006). *Remote Sensing Lecture Sheets GRS-20306*. Laboratory of Geo-Information Science and Remote Sensing. Wageningen University, Wageningen.

De Wit, C.T. (1958). *Transpiration and Crop Yields*. Institute of Biological and Chemical Research on Field Crops and Herbage. Wageningen, The Netherlands.

FAO. (1998). Crop Evapotranspiration (guidelines for computing crop water requirements). *Irrigation and Drainage Paper No. 56*. FAO, Rome, Italy.

Pelgrum, H. & Bastiaanssen, W.G.M. (1996). An intercomparison of techniques to determine the area-averaged latent heat flux from individual in situ observations: A remote sensing approach using the European Field Experiment in a Desertification-Threatened Area data. *Water Resources Rersearch*, vol. 32 (9):2775-2786.

Tasumi, M., Allen, R.G. & Trezza, R. (2008). At-Surface Reflectance and Albedo from Satellite for Operational Calculation of Land Surface Energy Balance. *Journal of Hydrology* and Engineering 13:2(51).

Van De Griend, A.A. & Owe, M. (1993). On the relationship between thermal emissivity and the normalized difference vegetation index for natural surfaces. *International Journal of Remote Sensing*, vol 14, issue 6.

WaterWatch. (2008) *The Surface Energy Balance Algorithm for Land (SEBAL)*. Retrieved November 28, 2008, from http://www.waterwatch.nl.

Wukelic, W.E., Gibbons D.E., Martucci, L.M. & Foote H.P. (1989). Radiometric calibration of Landsat Thematic Mapper thermal band. *Remote Sensing of Environment* 28: 339-347