BOT/91/001
Field Document 12

Land Use Planning for Sustainable Agricultural Development

BOTSWANA

AGRICULTURAL LAND USE PLAN OF CHANOGA AGRICULTURAL EXTENSION AREA

by

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LIST OF ABBREVIATIONS

AD	-	Agricultural Demonstrator
AEA	-	Agricultural Extension Area
AI	-	Artificial Insemination
ALDEP	-	Arable Lands Development Programme
APRU	-	Animal Production and Range Research Unit
APSRAMB	-	Animal Production and Range Assessment Model for Botswana
ARAP	-	Accelerated Rainfed Arable Programme
BAMB	-	Botswana Agricultural Marketing Board
BCU	-	Botswana Cooperative Union
BLDC	-	Botswana Livestock Development Committee
BMC	-	Botswana Meat Commission
BSD	-	Botswana Soil Database
CBPP	-	Contagious Bovine Pleuropneumonia
ceq.	-	cattle equivalent
COV	-	Coefficient of Variance
CPP	-	Council Physical Planner
CYSLAMB	-	Crop Yield Simulation and Land Assessment Model for Botswana
DAO	-	District Agricultural Officer
DAR	-	Department of Agricultural Research
DAS	-	District Agricultural Supervisor
DDP	-	District Development Plan
DLUPU	-	District Land Use Planning Unit
DMI	-	Dry Matter Intake
DOD	-	District Officer Development
DOL	-	District Officer Lands
DWA	-	Department of Water Affairs
DWNP	-	Department of Wildlife and National Parks
FAP	-	Financial Assistance Policy
FMD	-	Foot & Mouth Disease
ILWIS	-	Integrated Land and Water Information System
LAC	-	Livestock Advisory Centre
LPS	-	Livestock Production Specialist (LUPSAD project)
LSU	-	Livestock Unit
LUPSAD	-	Land Use Planning for Sustainable Agricultural Development project
m asl	-	meters above sea level
MoA	-	Ministry of Agriculture
NDB	-	National Development Bank
NDP	-	National Development Plan
NGO	-	Non-Governmental Organization
PET	-	Potential Evapotranspiration
RAO	-	Regional Agricultural Officer
RARO	-	Regional Agricultural Research Officer
SLOCA	-	Services to Livestock Owners in Communal Areas
STD	-	Standard Deviation
SVO	-	Senior Veterinary Officer
TDS	-	Total Dissolved Solids
UTM	-	Universal Transverse Mercator (map projection)
VA	-	Veterinary Assistant
VDC	-	Village Development Committee

EXECUTIVE SUMMARY

BACKGROUND

1. In cooperation with the Regional Agricultural Officer, the Chanoga Agricultural Extension Area (AEA) was chosen for this study, because of the practiced mixed farming systems and its representative natural resource base. Many inhabitants of the area combine rainfed arable farming with the rearing of cattle or goats and with the collection of veld products.

2. This land use plan concentrates on the evaluation and optimization of the present (mainly crop and animal based) production systems. As the Chanoga AEA serves as an example, conclusions and recommendations are valid for other AEAs in the Maun Agricultural Region with comparable agro-ecological characteristics and similar land uses problems and constraints.

3. The Chanoga AEA is located in the eastern part of Ngamiland District at approximately 30 km east of Maun. It comprises the villages/settlements of Mawana in the west, Chanoga, Tsibogolamatebele in the centre and Xhana in the east and measures about 783km^2 (78,295 ha). The area is entirely situated at an altitude of approximately 930-950m asl.

PHYSICAL ENVIRONMENT

4. The climate in the AEA is semi-arid, characterized by hot and relatively moist summers and relatively cool and dry winters. The average annual temperature is 22.4°C, whilst the mean annual rainfall amounts 446.4mm, of which 90% falls during the months November to March. The interannual variation in rainfall is high, reflected in a standard deviation of 170.4mm and a coefficient of variance of 38.2%.

5. Three land divisions are found: alluvial and lacustrine system and sandveld. Sandy soils, poor in nutrients, Eutri-Haplic Arenosols, are most frequent and mainly occur on higher positions. The second most widespread soils are Areni-Haplic Luvisols, confined to depressions in the sandveld and the fossil floodplain. The last soils are the most suitable for arable farming, and are characterized by a slight clay increase in depth, a good water holding capacity and moderate nutrient levels. Different Calcisols with a (petro)calcic horizon, at times limiting the soil depth, occur in depressions and pans throughout the area.

6. No significant water erosion has been observed. However, wind erosion and deposition happens regularly on land units with a sparse vegetation cover and a fine sand to sandy loam textured topsoil. The loss of topsoil structure and nutrient depletion of farmers' fields are ongoing.

7. The Boteti River has not been flowing since 1992. Approximately 200 shallow hand dug wells are located in the floodplain, used for domestic consumption and livestock watering. Boreholes provide water to the village of Chanoga, to the Shorobe Quarantine Camp, and to eight residential plots. Several boreholes have not been developed or are out of use. Six cattleposts have access to deep hand dug wells.

8. Eleven vegetation units have been identified, varying in structure from grassland and shrub savanna to savanna and woodland. The most common vegetation type occupies 48% of the area and is typified by the species *Lonchocarpus nelsii*, *Terminalia sericea*, *Bauhimia petersiana* and *Commiphera pyracanthoides*.

9. The main present land uses are livestock production (extensive grazing covering 97% of the AEA), rainfed arable farming (2 %) and settlements (1%). Veld product collection takes place throughout the study area.

10. All natural resource characteristics have been combined in 10 land units. These units form the basis for the analyses of the production systems.

SOCIO-ECONOMIC ENVIRONMENT

11. The Chanoga AEA had a *de facto* population of 1056 people during the 1991 Census. Considering an annual growth rate of 2.6%, the projections for 1994 and 2004 are 1201 and 1513 people, respectively. The sex ratio (males/100 females) is 109.5, as opposed to 93.3 for the Ngamiland south Census District.

12. The total number of households is 233, of which 49% is male headed and 51% female headed. The majority (57%) of household heads is over 50 years of age. Only 10% of the total is between 20-29 years old. The average number of people per household is 5.5.

13. The planning area is situated in communal land and falls under the jurisdiction of the Tawana Land Board.

14. Most households obtain an income from crop and livestock production, sales of veld product, Drought Relief Programmes (labour based and arable subsidies) or wage labour and remittances.

15. Based on the area cultivated, available farm labour, capital/cattle equivalents and access to draught power, a stratification of farming households was made. A total of 45% belongs to the poor class, 28% to the well-off class and 27% of the households is classified as rich. Of the female headed households 66% is classified as poor, while 34% is well-off. Male headed households are rather evenly distributed over all three classes: 37% poor, 26 % well-off and 37% rich.

16. All interviewed farmers have knowledge of ARAP, ALDEP and Drought Relief schemes, while 83% has heard about FAP and 75% of AE-10. All farmers have benefitted from drought relief packages and 36% obtained implements through ARAP and/or ALDEP.

PRESENT LAND USE

17. During the season 1993/94, 872 ha was used for rainfed arable farming; an average of 3.1 ha per household. Of the total area cultivated, 96% was broadcasted and 4% was row planted. Crops grown are maize, sorghum, cowpeas, millet, sweet reed and melons. Yields vary from 1-3 (70 kg) bags/ha. Most farmers use donkeys for ploughing; 34% of the households hired a contractor (donkeys or tractor) to plough. Ploughing/planting is normally done after Christmas. One weeding operation is conducted, where hardly any pest and decease control measures are taken. Only bird scaring is carried out regularly.

18. Two major crop production systems have been recognized, based on a difference in timing of operations and management of human resources and implements: the rotational management system (several adult family members) and the single farming household.

19. Molapo farming is practiced, when the Boteti River floods the fields located adjacent to the main channel.

20. The information given in this report on cattle ownership reflects the situation in 1995. Due to the cattle lung disease, all cattle on communal lands in the entire Ngamiland District (approximately 300,000 beasts) was destroyed in the second half of 1996, in a bid to curb the spreading of the disease to other districts.

21. Stock Census data of 1995 show a total of 1900 head of cattle, 1800 goats, 340 donkeys and 50 horses in the Chanoga AEA. The farm survey reveals a total cattle herd of 3500 animals, 4900 goats and 1160 donkeys. Based on the last figures, a household owns on average 15 head of cattle, 22 goats and 5 donkeys. However, 3% of all households, does not own any livestock, 37% no cattle (28% of all male and 61% of all female headed households), 23% no goats (19% of all male and 31% of all female headed households), while 12% is without donkeys (3% of male and 38% of female headed households).

22. Three major livestock production systems have been recognized. Extensive grazing of goats (birth rate 83%, death rate 26% and offtake rate 8%). Extensive grazing of a small cattle herd around settlements (calving rate 50%, calve mortality 45%, adult mortality 35% and offtake rates 9%). Extensive grazing of a medium sized herd around cattleposts (calving rate 60%, calve mortality 15%, adult mortality 20% and a yearly offtake rate 9%).

23. The following veld products are regularly harvested for sale or home consumption: fish, waterlily tubers (tswii), reeds (lethaka and mothebe), palm leaves (mokola), berries (motsintsila, morotologwa, mogwana and moretlwa), fibers for rope (*Sansevieria*), wild spinach (rothwe), devil's claw (sengaparile), thatching grass, fuelwood and poles (mopane and other trees).

LAND USE PROBLEMS AND CONSTRAINTS

24. Low rainfed crop yields are caused by constraints related to the natural environment (adverse climate, poor soils and land degradation processes), by constraints related to crop management (choice of crop, low labour productivity and poor crop husbandry) and by other constraints (low adoption rate of extension messages and use of assistance programmes, long distance from suppliers and poor marketing facilities).

25. Although not regularly practiced, molapo farming yields are hampered by similar constraints as dryland farming, with special reference to poor land preparations and crop husbandry.

26. The main constraint of horticultural production is the unreliability of surface water for irrigation. Other problems are related to a lack of knowledge of vegetable growing and to pest and disease management.

27. Most livestock production systems function sub-optimally and are characterized by problems related to the natural environment (unreliable biomass production, water shortages and range degradation), by problems related to livestock management (poor range management, low input animal husbandry and low offtake rates) and by institutional (low adoption of veterinary extension) and marketing problems.

28. The collection of veld products is accompanied by constraints related to management of the resources (burning and veld fires and indiscriminate logging of trees) and poorly developed marketing channels.

29. The well being of many farming households has come under pressure in recent years, due to an unreliable drinking water situation and a decrease in income (caused by crop failure, loss of livestock and scarceness of veld products in years of drought).

LAND EVALUATION

30. The potential for rainfed crop production has been assessed with the use of CYSLAMB. Compared to the national picture, most land units have a moderately low (class D) to low (class E) suitability. The depressions are most suitable (class D), while the higher land elements are moderately suitable (class E).

31. When comparing the results of the rotational management system and the single farming household, it appears, that too much time is lost in rotating implements and labour in the former scenario, which leads to lower yields than the latter scenario. In order to investigate the scope for improvement of single farming households, 4 baseline, 3 intermediate and 1 optimal management system have been evaluated for maize, sorghum, millet, cowpea and groundnut, grown on the six most productive land units.

32. From the CYSLAMB crops, maize is the most draught sensitive and shows the lowest gross margins, when grown under baseline or intermediate management. Under optimal conditions it performs similar to millet and somewhat better than cowpea. Groundnut achieves the highest returns under all scenarios, followed by sorghum.

33. For diversification purposes, the most promising alternative crops have been listed. As cash crop can be considered: cluster bean, devil's claw, hibiscus, jugo bean, pigeon pea, prickly pear, sesame, sisal and sunflower. As fodder crop a choice can be made of: buffel grass, lablab bean, moth bean and siratro.

34. When the Boteti River flows, molapo farming has a potential. By improving the baseline management scenario with practices like harrowing, crop rotation, increased plant density and the use of fertilizer the a considerable yield increase can be achieved.

35. In order to stimulate horticultural production, an example of costings and returns for a home vegetable garden was made. An alternative source of cash income could be found in the establishment of backyard nurseries or small orchards. Also a financial projection of a small scale beekeeping project was made.

36. Two agroforestry systems have been designed, mainly to protect arable fields against wind erosion, but with the positive side effects as source for mulch, wood and fruits.

37. The range biomass production was assessed with APSRAMB. The sandveld has the best range condition. Despite average grazing biomass production figures of 1200-1600 kg dry matter/ha/yr, the range is not as productive as expected. This is caused by the relatively low digestibility of the occurring grass species. As cattle graze across land unit boundaries, 2 principal grazing areas have been considered, according to the 2 main cattle management systems. Grazing area A, stretches from the Boteti River to the southern 30% of the sandveld and comprises the small cattle herds, managed from the settlements. Area B, occupies the northern 70% of the sandveld and comprises the cattleposts. The actual grazing pressure (including trekked animals) in the entire AEA is 4250 LSUs.

38. Evaluation of existing cattle production systems for both the village grazing and the cattlepost situation have been carried out with APSRAMB. The improved management interventions controlled breeding, provision of supplementary feed and increased offtake rates were simulated and proved to be effective. A dramatic drop in the traditional village herd size was prevented by a supplementary feed gift, while the improved cattlepost herd expanded rapidly due to calving in the rainy season and supplementary feeding.

39. Two alternative animal based production systems have been evaluated: the production of ducklings and chicken eggs. The operations can be conducted separately or combined, and show a viable gross margin.

40. APSRAMB was used for the evaluation of several veld products. The average yearly production of lethaka reeds is calculated at 5800 kg/ha, which has a market value of P 2900/ha. For mopane a yearly biomass increment of 700 kg/ha is estimated, corresponding to 0.6 m^3/ha/yr with a value of P 30. The production of thatching grass in the sandveld is estimated at 2400 kg/ha, representing a market value P 2400/ha.

41. APSRAMB predicts an average yearly increment of woody biomass of 53,600 m^3/yr, for the entire AEA. This yearly production can supply fuelwood to 28,200 people and easily meets the needs of 2280 m^3 of the 1201 people living in the study area. The requirements of an increased population to 1513 people in 2004 are also fulfilled, and no shortage of this resource is foreseen in the near future.

42. To raise its income from controlled hunting area NG35, the Department of Wildlife and National Parks should either raise the single game license fees for citizens or change the use of NG35. Introduction of other types of wildlife utilization as tourist trophy hunting or wildlife/game ranching could be considered.

CONCLUSIONS AND RECOMMENDATIONS

43. A toolkit with extension messages has been prepared, which are targeted to each of the 5 farmer groups involved in rainfed crop production. The most important recommendations vary from the establishment of wind breaks, cultivation of smaller areas, the improvement of the draught power situation, timely planting, reduction of planting opportunities, row planting and crop rotation, use of inorganic fertilizer, choice of crop, to the introduction of alternative management practices and alternative crops.

44. By growing sorghum under the baseline scenario Bs3 (late planting, 3 plant occasions) on the total area cultivated, the grain requirements of the population of the AEA are not met; a subsistence ratio of 0.44 is achieved. When the improved scenario Im3 (early planting, 2 plant occasions) or the optimal scenario Op1 (early planting, 1 planting occasion) are adopted, a surplus is obtained compared to the requirements of the population in 1994 (ratio 1.38) and in 2004 (ratio 1.1), without increasing the area planted.

45. The sandveld grazing block seems to be slightly understocked. To alleviate the grazing pressure in the village are and the watering problem, boreholes should be drilled on the northern Boteti River bank. Water should be reticulated to the sandveld area. Small cattle owners should be motivated to form water development groups and ranching syndicates, in order to start controlled grazing in paddocked areas to assure a sustainable use of the grazing resource and to improve their production systems.

46. The local population's awareness should be increased concerning the value of veld products in the standing biomass. Sustainable harvesting techniques should be developed and quota set. The creation of a veld product marketing board to assist communities should be considered. The feasibility of a mopane coppicing project should be studied.

47. In order to improve farmers' well being, settlements and grazing areas should be provided with water.

48. To increase the crop and livestock production, the extension service should be better equipped to serve their clients. This upgrading should have a logistic component (provision of base maps, increased mobility of Ads and Vas and improved record keeping of farmers' production systems) and a technical side (larger packages of extension recommendations and more creative facilities to transfer the recommendations).

49. A restructuring of ALDEP should be considered, in order to increase the number of packages obtained. Future arable Drought Relief programmes should provide more production improving incentives and should not affect Ads' extension activities. A credit/saving scheme for small farmers should be designed.

50. Marketing facilities involving BAMB, LAC, BMC and BLDC should be improved. Suggestions for small scale village based (agro-)industries have been made. Infrastructural improvements (roads, electricity, telephone and alternative energy sources) should be considered.

51. Recommended land use on a land unit basis is shown in table format, based on the results of the land evaluation exercises and a simple suitability rating.

52. An implementation matrix showing main actors, activities, beneficiaries and timing has been included.

1 INTRODUCTION

One of the planned outputs in the framework of the FAO/UNDP/Government of Botswana project *Land Use Planning for Sustainable Agricultural Development* (LUPSAD) consists of detailed land use plans at Agricultural Extension Area (AEA) level.

In discussions between project management, concerned ALUPs and the client, the Regional Agricultural Officer (RAO) the Chanoga Agricultural Extension Area was chosen as study area. The Chanoga AEA is located in the Ngamiland East Agricultural District, which forms part of the Maun Agricultural Region.

The Chanoga AEA was selected for this exercise, because of the inclination of the majority of its population towards both rainfed arable farming and some form of livestock rearing. In addition, the gathering and/or sales of veld products is essential for the household food security among several groups of farmers.

Furthermore the Chanoga AEA is representative for the Ngamiland East Agricultural District in terms of its resources (soil, water and vegetation) and its land divisions (alluvium, lacustrine and sandveld).

The main objective of this agricultural land use plan is to evaluate the present ways of natural resources utilization and to assess the viability of the existing farming systems. Suggestions for improvements of actual land use practices and potential alternatives are given, after having been screened for their financial, environmental and social feasibility.

This land use plan mainly focuses on increasing the outputs of crop and animal based production systems, in a bid to improve the overall standard of living and well being of the people of the Chanoga AEA. As the Chanoga AEA was chosen as a role model, conclusions and recommendations reached can likewise be implemented in other AEAs with similar agro-ecological characteristics and comparable land uses problems and constraints in the Maun Agricultural Region.

In Chapter 2 the methodologies applied during this study are summarized. After a description of the physical environment (Chapter 3) and the socio-economic characteristics of the Chanoga AEA (Chapter 4), the major land use problems and constraints are discussed (Chapter 5). In Chapter 6 land evaluations are carried for the most prominent production systems, followed in Chapter 7 by an appraisal of alternative land use options. Conclusions and recommendations are presented in Chapter 8 and finally some suggestions are made to guide the implementation process of this land use plan in Chapter 9.

2 METHODOLOGY

2.1 General planning strategy

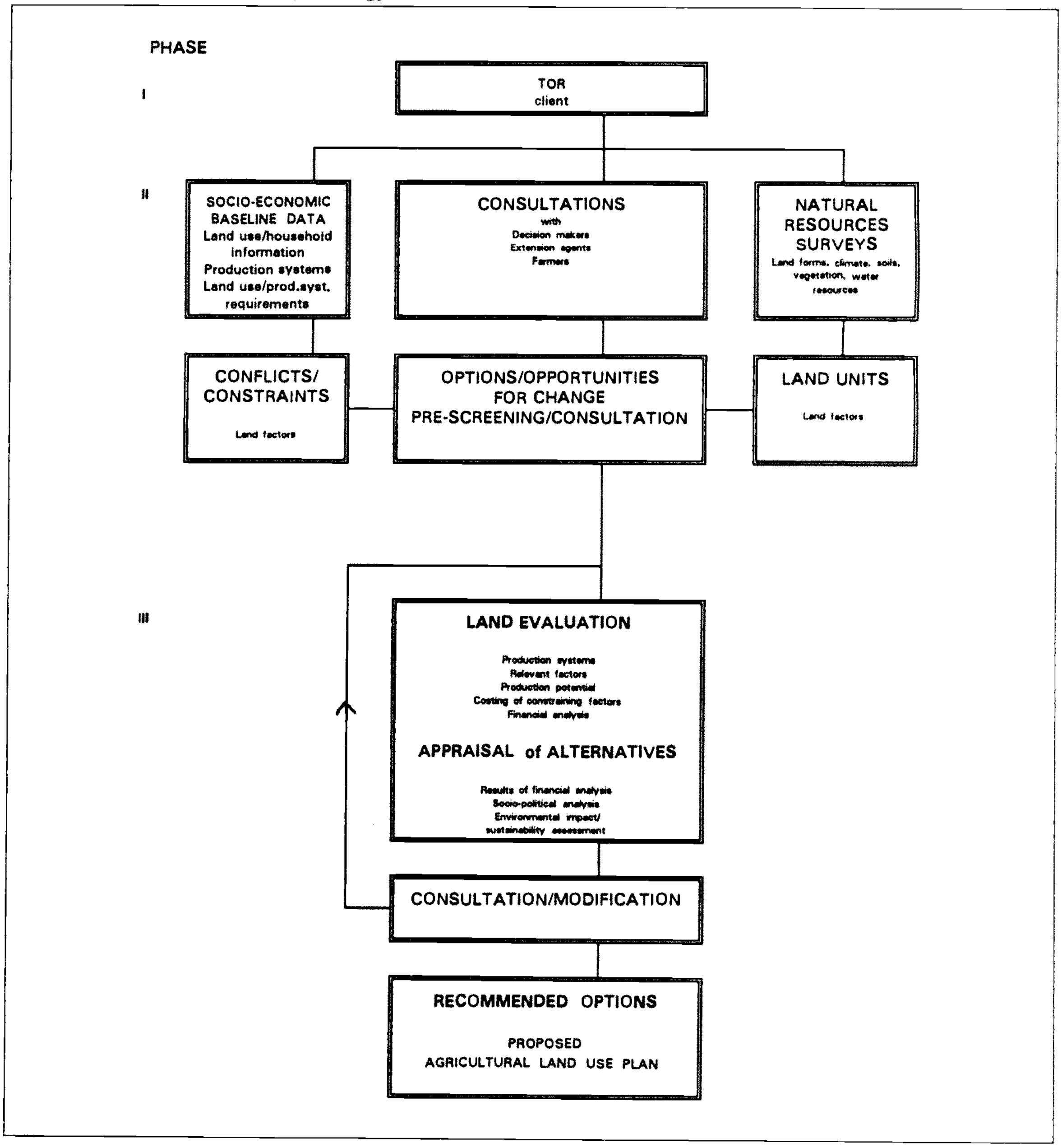
Ideally a land use planning exercise can be divided in three phases, see Figure 1 (from LUPSAD Working Group, 1995):

I. Drafting of Terms of Reference by the client. As this was the first exercise of this kind in the Maun Region, the selection of a study area took place informally. Hence no Terms of Reference were produced.

II. Consultation of authorities and beneficiaries, resulting in the collection of socio-economic baseline data and the identification of land use requirements. Natural resources surveys, providing an overview of the relevant land qualities.

III. Land evaluation procedures, leading to recommended options.

Figure 1. Land Use Planning Strategy



2.2 Data collection and analysis

The following surveys were carried out in the Chanoga AEA as part of the study:

1. **Soil survey.** First, a refinement of the existing 1:250,000 soil maps was made, using aerial photography, resulting in a preliminary 1:50,000 Soil Map with mainly single soil units. Subsequently, field checks consisting of 60 augerings, were carried out. Lastly, the preliminary map was finalized and presented at a scale of 1:120,000.

2. **Vegetation survey.** A 1:50,000 Vegetation Map was drafted with help of aerial photography, followed by 31 ground checks. In collaboration with Messrs M.J. Powell (LPS) and M.C. Bonyongo (Range Ecologist, MoA) the preliminary mapping units were typified, following the methodology described by Powell *et al.* (1996). The canopy cover of the tree, shrub, and herb/grass strata, as well as the site in total were estimated with the help of a Bitterlich gauge (10cm wide cross bar). Furthermore the species composition of each stratum was recorded.

3. **Waterpoint survey.** With a Global Positioning System most of the boreholes registered in the Ngamiland DLUPU Waterpoint Database and a great number of new boreholes, hand dug wells and wellpoints have been located and mapped.

4. **Survey of infrastructure.** With a Global Positioning System the alignment of several roads and tracks, which form some of the boundaries of the Chanoga AEA, have been mapped. Also recorded were the circumference of the major villages and settlements, the alignment of a powerline, cattle and smallstock crushes and diptanks, residential plots and a few projects along the Boteti River and the presence of silcrete stones in the Boteti River bed have been recorded.

5. **Socio-economic survey.** 46 general and 12 in-depth interviews (approximately 20% of the households) have been conducted, in order to collect data on the household composition, economic activities and constraints of the population of the Chanoga AEA. The interview results form the basis for a classification of the farming households.

In addition to the above, information was collected from the Drought Relief Report and Seed Distribution Report for the cropping season 1993/94 from the Agricultural Demonstrator (AD) Chanoga, cattle crush figures from the Senior Veterinary Officer (SVO), Population Census figures and an update of meteorological data for the Maun synoptic and rainfall station from the Department of Meteorological Services Headquarters in Gaborone.

Topographic map sheets 1923D3, 1923D4, 2023B1 and 2023B2 at scale 1:50,000 (Department of Surveys and Lands 1970-1988) served as basemaps for maps produced during this study. The 1:250,000 Soil Maps of Maun and Toteng (Verbeek, 1989) were used as basis for the soil map. Aerial photography at scale 1:50,000 belonging to the Okavango Delta Block contract (1983) was extensively consulted; run 21 (132-134), run 22 (42-50), run 23 (05-12), run 24 (93-103), run 25 (02-05,09,10). The Landsat-5 TM image no. 174/74 taken on May 13 1994, at scale 1:250,000, was very useful for infrastructure interpretations, basemap updating and the mapping of present land use.

To define the vegetation units, a manual clustering of the 31 field observation was carried out, based on the structure and the presence of prominent species. The structure of the units was classified according to the definitions used in the description of sites of soil profiles of the Botswana Soil Database (Remmelzwaal and Van Waveren, 1988). From a table showing the occurrence (percentage cover) of all species per vegetation unit, the prominent species typifying each unit were derived. A maximum of four species was chosen to characterize each unit on the ground of the highest number of occurrences and the highest cover percentages within each unit. Subsequently, all observations were entered in the Botswana Vegetation Database. Lastly, the "*creveg.exe*" module related to APSRAMB was run, which converts the vegetation units from the

Botswana Vegetation Database to a format for use in APSRAMB. It also calculates the average canopy cover percentage for the five identified vegetation strata. The preliminary map at scale 1:50,000 was finalized and presented at a scale of 1:120,000.

The Present Land Use Map was drawn up from the Landsat TM image of May 1994, completed with aerial photography and field observations.

The Land Unit Map was construed based on the geomorphology of the study area complemented with information on soils, water resources, vegetation and present land use.

The following software packages and databases were used for the evaluation of crop and livestock production systems and for the formulation and presentation of recommendations:

- APSRAMB Version 2.1 for range biomass calculations and herd projections (Powell, 1996, Powell and Pulles, 1996 and Pulles, 1996)
- Botswana Soil Database (BSD) for retrieval of soil data (Van Waveren, 1988)
- Botswana Vegetation Database (BVD) for storage and retrieval of vegetation data (Powell and Pulles, 1996)
- CYSLAMB Version 2.03 for crop yield simulation (De Wit *et al.*, 1993, Radcliffe *et al.*, 1994, Bekker *et al.*, 1994)
- ECOCROP 1 for selection of alternative crops (FAO, 1994)
- ILWIS Version 1.41 for map production (ITC, 1994)
- METEO Database for retrieval of meteorological data (Schalk, 1990)
- Waterpoint Survey Database Ngamiland for existing waterpoint data (DLUPU, 1989)

The required soil parameters for running CYSLAMB have been summarized in one table. The total area covered by each soil type on a per land unit basis was calculated by ILWIS and was derived from the digitized Soil and Land Unit Map. A summary table has been attached as annex.

The necessary soil and vegetation parameters to assess the range biomass production through APSRAMB have been presented in four tables. A fifth annexed table indicates in what land unit each vegetation type is found and on what soil units it occurs. This information was compiled by combining the Vegetation Map with the Land Unit Map and the Soil Map respectively, through the ILWIS Copy&Merge facility. By doing so, the weighting factors (in the form of the area coverages) of the different soils for each vegetation unit per land unit could be obtained, which were used to determine the biomass production of each vegetation unit through APSRAMB.

In principal, the area coverages of the land unit map table should reconcile with the area coverages of the three individual maps (Land Unit, Soil and Vegetation Map); some manual corrections, however, were necessary.

For the final analysis of the production potential of the area, the land units are taken as the basic unit for comparison, as each land unit forms a typical combination of resources.

This report has been written along the lines proposed in the 4th Draft of the *Guidelines for Agricultural Land Use Planning in Botswana* (LUPSAD Working Group, 1995). This had two reasons. Firstly this study served as a test case, to see how well the Guidelines could be applied in practice and at which points possible improvements could be made. And secondly using the Guidelines provided a framework for standardization of the land evaluation procedures and for the structure of the report. The Chapter Appraisal of Alternatives of the *Guidelines* has not been followed strictly, and where possible proposed procedures have been integrated in Chapter 6 Land Evaluation of this document.

2.3 Consultations

During the course of the preparation of the land use plan, discussions were held with the following persons and institutions:

1. In the data collection stage: RAO and support staff, District Agricultural Officer (DAO) and District Agricultural Supervisor (DAS), AD, SVO, Regional Agricultural Research Officer (RARO), farmers, District Officer Lands (DOL), Council Physical Planner (CPP) and staff members of the Tawana Land Board.

2. In the data analysis stage: local authorities at village level (Village Development Committee (VDC), Headmen and farmers committees).

3. While drafting recommendations and at the presentation of results: RAO and support staff (especially staff from Forestry and Beekeeping made substantial contributions to this report), SVO and District Land Use Planning Unit (DLUPU).

2.4 Previous studies

The following general studies and plans covering the Chanoga AEA have been used: IUCN (1992) *Review of the Southern Okavango Integrated Water Development Plan*, NWDC (1989) *Ngamiland District Development Plan 1989-1995*, SMEC (1987) SOIWDP *Irrigated Agricultural Development Potential*.

During the cropping season 1994/1995, a series of on-farm crop trials was carried out by the LUPSAD project, which took place in 5 AEAs in the Ngamiland East Agricultural District. Two trials were held in the Chanoga AEA. The report *On-farm crop trials cropping season 1994-1995. Results and evaluation* (Bekker, 1995) was consulted.

The *Guidelines for Land Allocation along the River Banks in the Maun Area* (Bekker and Boom, 1995) produced by the Ngamiland DLUPU and accepted by the Tawana Land Board were produced simultaneously with this study and formed a source of inspiration for this report.

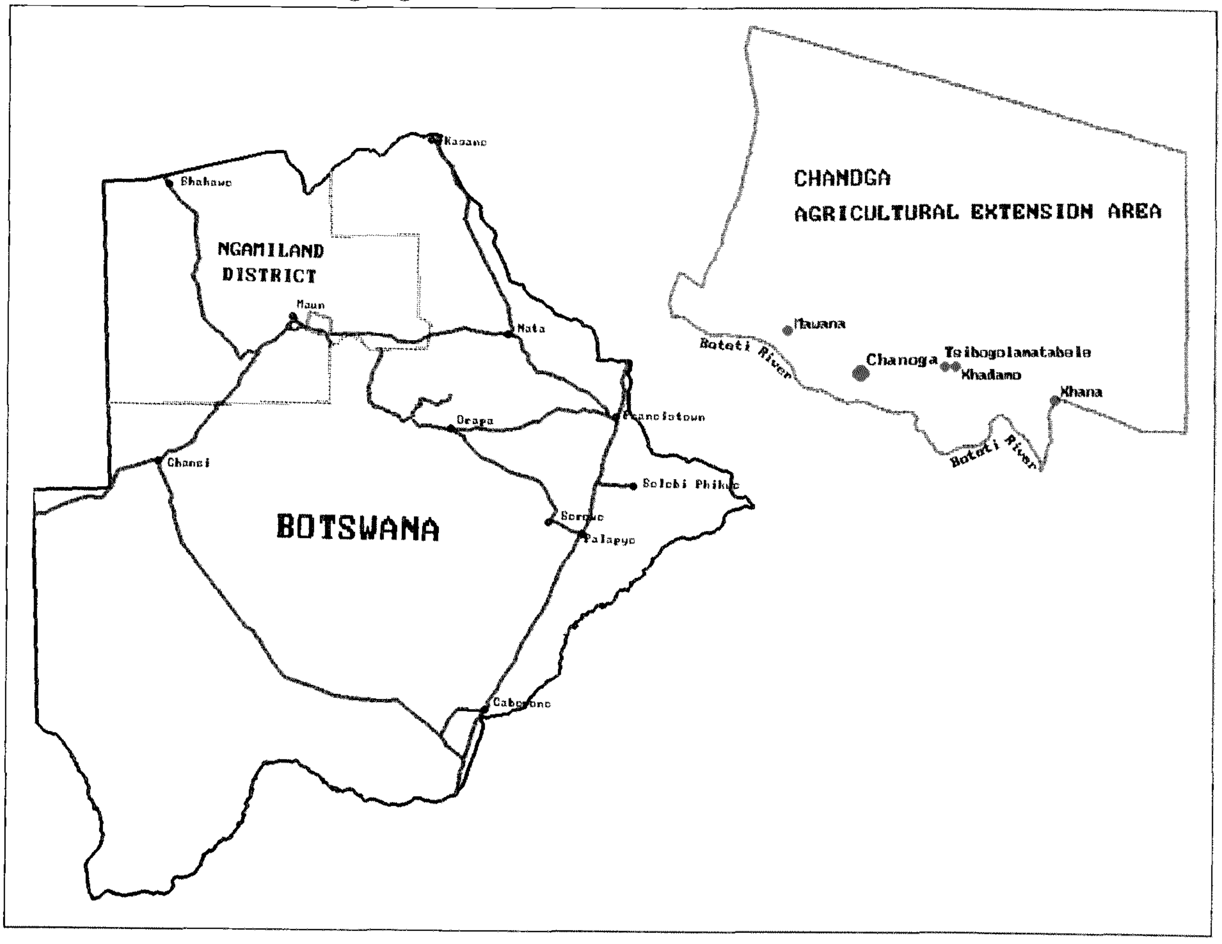
3 LAND RESOURCES INFORMATION

3.1 Location

The Chanoga Agricultural Extension Area is situated in the Ngamiland East Agricultural District, which forms part of the Maun Agricultural Region. The study area is entirely located in the Ngamiland Administrative District.

In terms of geographical location, Chanoga AEA is approximately confined by latitude 19°55'S and 20°13'S, and longitude 23°32'E and 23°53'E (see Figure 2). The AEA falls in grid belt 34 of the Universal Transverse Mercator (UTM) projection, roughly between the coordinates 7,795,000m and 7,762,000m Northing and 764,000m and 802,000m Easting. More precisely, the southern boundary is formed by the Boteti River. For mapping purposes the river is included in the Chanoga AEA, where it is in fact shared with the Tatamoga/Makalamabedi AEA. The eastern border consists of a fence, coinciding with the western extension of the Makalamabedi Artificial Insemination Camp and the Botswana Livestock Development Committee (BLDC) Ranch. The old Francistown Road, from the Protectorate era, delineates the northern boundary, while the western border constitutes of a sand track functioning as firebreak.

Figure 2. Location of Chanoga Agricultural Extension Area



Both the old and the new Nata-Maun Road run east-west through the southern portion of the AEA. The centre of the Chanoga AEA is situated approximately 35km east of Maun. The extension area encompasses the villages/settlements of Mawana in the west, Chanoga and Tsibogolamatebele in the centre and Xhana in the east. The Chanoga AEA measures 78,295 ha, which corresponds with approximately 800km^2.

3.2 Climate

The climate of northern Botswana is influenced by the presence of the southern subtropical high pressure belt, located at approximately 30° south. This belt causes large scale downward air movements. The upper atmosphere is warmed up, which results in stable atmospheric conditions. As a consequence, rainfall, mainly occurring in isolated convection showers, is low and has an erratic character, both in time and space. The summer rainfall is determined by the southward movement over Zambia of the Intertropical Convergence Zone (Bhalotra, 1987).

According to the Köppen classification (Köppen and Geiger, 1936) the study area has a Bsh climate; a semi-arid steppe climate, which is characterized by hot and relatively moist summers and relatively cool and dry winters (mean annual temperature > 18°C and mean annual precipitation > 400mm.)

The nearest synoptic and rainfall station to the Chanoga AEA is located in Maun. Table 1 shows a summary of the synoptic data for the Maun station (after Department of Meteorological Services, 1984 and METEO database). Monthly rainfall data for Maun are presented in Table 2 (after METEO database and updates from the Department of Meteorological Services, 1995 oral comm.).

Table 1. Synoptic data Maun Meteo station

METEO STATION: MAUN — Latitude: 19°59 S — Longitude: 23°25 E — Height: 945 m asl

MONTH	TEMPERATURE (°C)				SUNSHINE (hr/day)	RELATIVE HUMIDITY (%)		WIND (km/hr)	PET (mm)	FROST DAYS (days/month)	
	Mean Max.	Mean Min.	Extreme Max.	Extreme Min.		08.00	14.00			Air	Ground
January	31.6	19.5	40.0	9.2	8.0	76	48	9.4	179	0.0	0.0
February	31.4	18.9	37.2	10.6	8.1	78	48	9.0	159	0.0	0.0
March	31.3	17.8	39.5	6.2	8.5	75	42	9.4	161	0.0	0.0
April	29.9	15.0	35.0	4.4	9.1	70	36	8.9	140	0.0	0.0
May	27.5	9.6	33.0	−1.1	10.0	64	27	8.6	123	0.0	0.2
June	25.0	6.9	30.6	−5.8	9.5	64	27	9.1	105	0.0	7.8
July	25.1	6.9	31.3	−3.6	9.8	62	25	9.6	114	0.0	1.7
August	28.3	9.8	35.2	3.5	10.3	52	20	10.4	147	0.0	0.1
September	32.2	14.8	38.6	3.9	10.1	40	19	12.3	184	0.0	0.0
October	34.1	18.6	41.4	9.0	9.5	44	23	13.8	207	0.0	0.0
November	33.0	19.4	41.7	9.4	8.6	57	32	12.1	199	0.0	0.0
December	32.1	19.4	40.6	8.4	8.3	69	42	10.7	193	0.0	0.0
Annual avg/total	30.1	14.7			9.2	63	32	10.3	1911	0.0	9.8
Record (years)	(1959−80)		(1941−80)		(1959−80)	(1964−79)		(1967−80)	(1964−87)	(1964−87)	

The climatic data discussed in the following three sections is based on the figures of the Maun weather station.

3.2.1 Air temperature, sunshine, humidity and wind speed

The average annual temperature for the Maun weather station is 22.4°C. The mean maximum air temperature varies from 25.0°C in June to 34.1°C in October and the average minimum air temperature from fluctuate between 6.9°C in June/July to 19.5°C in January. No days with air frost have been recorded. Ground frost, however, occurs mainly in June and July with an average of 9.8 days/yr.

Sunshine hours are lowest in January (8.0 hours/day) due to the high cloud cover during the rainy season and highest in August (10.3 hours/day) towards the end of the winter.

Table 2. Monthly and annual rainfall data (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1922	120.4	117.7	95.4	8.9	12.4	0.0	0.0	0.0	0.0	24.4	24.4	94.6	498.2
1923	14.4	47.4	188.7	0.0	0.0	0.0	0.0	0.0	0.0	1.0	26.1	35.6	313.2
1924	no data available												0.0
1925	62.6	27.7	78.6	14.0	9.2	0.0	0.0	0.0	13.7	1.3	9.6	83.1	299.8
1926	38.4	41.5	10.7	17.8	0.0	0.0	0.5	0.5	0.0	16.8	38.8	102.1	267.1
1927	161.6	39.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67.3	3.3	39.3	311.0
1928	113.0	53.8	14.2	0.0	0.0	0.0	0.0	0.0	0.6	4.3	71.9	87.2	345.0
1929	47.5	66.3	9.5	90.9	0.0	0.0	0.0	0.0	1.3	0.8	22.8	108.4	347.5
1930	88.8	103.0	84.1	35.8	0.0	0.0	0.0	0.0	0.0	1.8	12.7	106.7	432.9
1931	25.4	174.2	273.8	14.0	0.0	0.0	0.0	0.0	0.0	11.4	46.5	41.8	587.1
1932	89.7	20.0	15.3	0.0	0.0	0.0	0.0	0.0	0.0	2.9	13.7	51.4	193.0
1933	122.7	110.5	44.9	47.7	2.6	0.0	0.0	0.0	0.0	0.0	115.6	56.7	500.7
1934	73.8	56.6	16.0	13.2	0.0	0.0	0.0	0.0	0.0	3.3	56.9	49.4	269.2
1935	106.9	47.5	269.9	28.9	33.6	0.0	0.0	0.0	0.0	4.3	57.3	63.6	612.0
1936	60.0	169.4	39.1	9.5	0.0	0.0	0.0	0.0	0.0	2.8	14.8	84.4	380.0
1937	138.8	46.0	19.6	48.3	0.0	0.0	0.0	0.0	0.0	0.3	16.8	44.1	313.9
1938	62.4	215.5	43.1	0.5	0.0	1.0	0.0	0.0	0.0	33.0	115.4	100.2	571.1
1939	69.2	56.5	153.1	90.9	0.0	0.0	0.0	0.0	10.4	22.1	36.2	101.2	539.6
1940	151.1	59.9	0.0	10.2	0.0	0.0	0.0	0.0	4.3	10.9	14.5	44.0	294.9
1941	31.5	71.6	120.7	9.8	13.7	0.0	0.0	0.0	0.0	40.6	36.0	56.9	380.8
1942	93.4	11.2	57.8	82.4	18.3	0.0	0.0	0.0	0.0	30.9	0.8	96.8	391.6
1943	145.8	318.7	15.8	6.9	0.0	3.3	0.0	0.0	0.0	5.0	23.9	72.3	591.7
1944	17.9	43.0	161.8	1.0	2.0	0.0	0.0	0.0	0.0	15.9	38.1	38.4	318.1
1945	395.9	95.3	0.0	0.0	3.8	0.0	0.0	0.0	0.0	15.1	48.2	81.4	639.7
1946	83.5	32.0	125.4	0.0	0.0	0.0	0.0	0.0	0.0	10.3	21.9	16.3	289.4
1947	110.9	174.6	172.1	67.9	0.0	0.0	0.0	0.0	0.0	1.0	92.0	102.0	720.5
1948	82.1	7.7	128.2	1.3	0.0	10.4	0.0	0.0	0.3	23.1	61.6	19.6	334.3
1949	106.9	118.7	40.4	38.3	22.8	0.0	0.0	0.0	0.0	5.1	61.6	132.9	526.7
1950	100.9	72.5	51.4	36.8	22.6	0.0	0.0	0.3	0.0	0.0	10.1	129.8	424.4
1951	91.5	108.4	10.3	0.3	10.2	0.3	0.0	0.0	0.0	61.0	70.4	88.6	441.0
1952	92.8	157.1	77.4	21.3	0.8	0.0	0.0	0.0	0.0	32.7	169.6	77.9	629.6
1953	142.1	96.7	86.9	16.1	0.0	0.0	0.0	0.0	0.0	4.8	77.1	136.8	560.5
1954	183.1	245.7	167.9	20.2	2.3	0.0	0.0	0.0	0.0	9.3	11.9	223.1	863.5
1955	54.0	129.1	53.3	25.6	2.8	0.0	0.0	0.0	0.0	32.2	48.1	82.3	427.4
1956	72.3	104.8	92.2	14.8	0.0	1.5	0.0	0.0	11.6	4.4	42.4	64.0	408.0
1957	230.9	124.9	88.6	3.1	0.0	0.0	0.0	0.0	2.1	29.4	27.5	95.9	602.4
1958	133.1	71.0	66.0	12.5	5.3	1.8	0.7	0.0	1.1	54.3	36.1	101.8	483.7
1959	30.5	73.4	21.0	71.0	16.2	3.3	0.0	0.0	0.1	2.1	18.3	80.2	316.1
1960	111.8	133.2	145.3	12.2	24.4	0.0	5.4	0.0	0.0	2.7	54.2	49.3	538.5
1961	155.1	35.5	8.3	41.2	0.0	0.0	0.0	3.9	0.0	3.8	30.0	35.2	313.0
1962	208.7	58.0	66.6	12.8	4.8	0.3	0.0	0.0	0.0	4.4	79.9	113.6	549.1
1963	79.2	70.1	17.6	0.0	0.0	0.0	0.0	0.0	0.0	29.8	98.9	208.7	504.3
1964	33.2	54.0	6.4	58.0	0.0	0.0	0.0	0.0	0.2	16.1	50.0	49.8	267.7
1965	101.1	160.0	123.6	59.7	0.2	17.1	0.0	0.0	2.3	0.2	35.6	52.5	552.3
1966	137.6	186.1	20.8	120.4	0.0	0.0	0.0	0.0	29.2	0.0	2.7	108.3	605.1
1967	109.9	104.2	81.3	65.5	33.8	0.0	0.0	0.0	0.0	8.8	111.9	64.1	579.5
1968	50.2	245.3	36.9	15.4	0.1	0.0	0.0	9.6	0.0	2.1	70.2	59.9	489.7
1969	123.6	21.2	9.2	1.4	0.0	0.0	0.0	0.0	21.0	10.1	67.6	13.0	267.1
1970	108.4	12.4	34.4	44.6	0.0	0.0	0.0	0.0	8.6	0.0	58.7	159.7	426.8
1971	260.3	51.5	192.9	19.8	0.0	0.0	0.0	0.0	1.6	9.7	66.8	94.4	697.0
1972	80.8	67.5	21.9	14.8	0.0	0.0	0.0	0.0	0.0	10.5	2.0	45.2	242.7
1973	347.0	365.7	17.9	50.1	0.0	0.0	0.0	0.0	0.0	100.8	43.9	262.2	1187.6
1974	161.1	90.8	191.4	71.3	3.5	0.0	0.0	0.0	11.1	6.5	98.7	27.8	662.2
1975	113.6	68.1	108.3	3.7	2.7	0.0	0.0	0.0	0.0	1.2	10.5	71.2	379.3
1976	114.8	98.4	126.5	19.2	4.0	0.0	0.0	1.2	12.0	25.3	74.2	37.7	513.3
1977	91.9	226.2	37.4	12.1	14.4	12.0	0.0	0.0	31.9	3.1	77.1	226.7	732.8
1978	124.8	30.2	25.8	7.3	0.0	0.0	0.0	0.1	0.2	11.2	19.0	73.2	291.8
1979	91.0	290.5	42.5	1.2	0.0	0.0	0.0	0.0	0.0	26.8	20.1	36.5	508.6
1980	126.3	160.6	92.9	5.2	4.5	0.0	0.0	0.0	1.9	3.0	74.0	27.7	496.1
1981	24.5	17.0	11.3	14.9	0.0	0.0	0.0	0.0	0.0	8.2	74.7	58.6	209.2
1982	98.6	11.4	25.1	19.5	15.8	1.0	0.0	0.0	0.0	101.1	84.2	34.6	391.3
1983	20.0	17.9	81.8	8.3	0.9	0.0	0.0	0.3	0.0	20.0	53.5	153.4	356.1
1984	76.8	41.8	55.1	2.4	0.0	0.0	0.0	0.0	0.5	20.2	92.5	12.6	301.9
1985	53.8	70.0	34.6	52.4	10.7	0.0	0.0	0.0	0.0	21.6	7.8	134.7	385.6
1986	32.2	60.3	27.3	0.0	0.0	0.0	0.0	0.0	19.2	49.6	49.3	57.1	295.0
1987	38.2	104.0	79.4	19.2	0.0	0.0	0.0	0.0	3.9	8.5	6.1	92.3	351.6
1988	215.5	180.2	44.3	96.3	0.0	0.0	0.0	0.0	7.6	12.9	14.5	46.0	617.3
1989	87.1	110.1	33.3	17.3	0.0	0.0	0.0	0.0	0.0	0.0	7.2	40.1	295.1
1990	84.1	110.1	33.3	17.3	0.0	0.0	0.0	0.0	0.0	17.4	5.5	41.5	309.2
1991	177.6	133.9	122.7	0.0	0.0	0.0	0.0	0.0	5.8	28.5	13.3	78.4	560.2
1992	50.1	4.9	87.3	5.0	0.0	0.0	0.0	0.0	1.4	6.6	40.7	55.1	251.1
1993	66.5	122.0	15.4	47.4	0.0	0.0	0.7	0.0	8.2	14.3	23.9	154.7	453.1
1994	275.0	50.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.0	15.2	390.4
1995	27.0	14.4	48.3	0.0	0.0	0.0	0.0	0.0	21.6	11.2	16.6	54.1	193.2
MEAN	106.9	97.1	68.6	24.6	4.1	0.7	0.1	0.2	3.2	16.2	44.8	79.9	446.4
STD*	71.5	75.7	62.7	28.0	7.9	2.7	0.6	1.2	6.9	20.7	33.9	50.8	170.4
COV**	66.9	78.0	91.4	113.9	193.9	383.4	641.8	556.5	214.1	127.6	75.7	63.5	38.2

* Standard Deviation ** Coefficient of Variance

The relative humidity is usually higher in the morning than during the afternoon. Through the year the highest records are for February (78-48%) in the middle of the rainy season and the lowest figures are measured in September (40-19%) during spring.

The average wind speed reaches a maximum in October (8.8 km/hr) and a minimum in the month of May (5.5 km/hr). The winds are mild and the predominant direction is from the east. Strong winds may occur in relation with isolated thunderstorms.

3.2.2 Rainfall and potential evapotranspiration

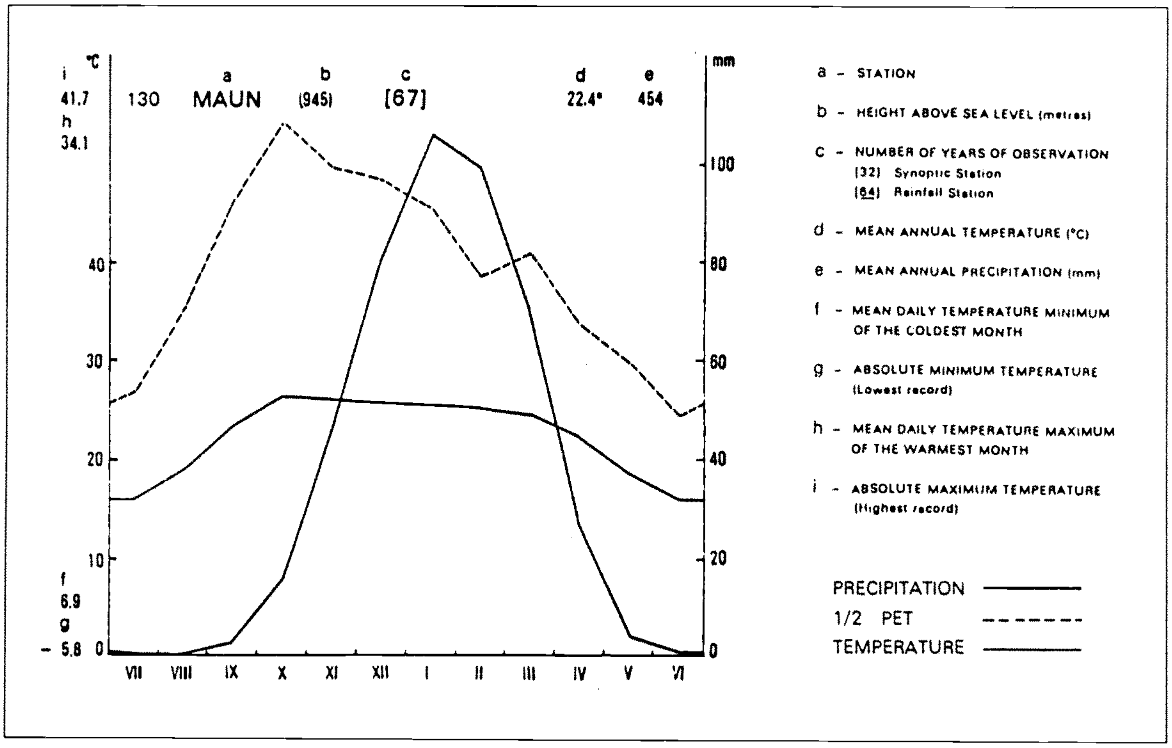
The long term average annual rainfall for the Maun station (1922-1995) is 446.4mm (see Table 2), of which around 90% falls during the summer months of November to March. January and February are the wettest months and virtually no rain is recorded in June, July and August. The interannual variation in rainfall is high, reflected in a standard deviation of 170.4mm and a coefficient of variance of 38.2%.

The potential evapotranspiration (PET), calculated after Penmann and modified by SMEC (1987) varies between 105mm in June and 207mm in October. The average annual PET is 1911mm.

For land evaluation of rainfed arable farming *effective rainfall* figures are used. The effective rainfall is calculated by summing daily rainfall larger than the Penman PET into dekadal totals. Range assessments are based on crude dekadal rainfall data. For the running of the crop- and livestock simulation models (see Chapter 6), a range of rainfall years was. Tyson (1978) argues, that the periodicity in the rainfall pattern follows a 20 year cycle. In this study the range from 1974-1993 was used, as these years represent the generally wetter 1970's and the drier 1980's.

The curves of the monthly averages of the air temperature, the rainfall and half the potential evaporation can be combined in a climatic diagram. Figure 3 shows the situation for the Maun meteorologic station. The temperature and the evapotranspiration curves peak in early summer (October-November), while the rainfall curve peaks three months later (January-February).

Figure 3. Climatic diagram Maun meteorologic station



3.2.3 Soil temperature and soil moisture

Soil temperature influences seed germination and root development of crops and plants and the microbiological activity in the soil. Soil temperature is determined by cloud cover, slope, soil colour, soil moisture and vegetation (ground and canopy cover).

For Maun the mean annual soil temperature at 60cm depth is around 26°C. The difference between the average summer and the average winter soil temperature at 60cm depth is approximately 8°C. Since this difference exceeds 5°, the soil temperature regime can be classified as *hyperthermic* according to the Soil Taxonomy (Soil Survey Staff, 1975). At the surface the diurnal and seasonal variations in soil temperature are greatest; they diminish with increasing depth.

Considering the rainfall data, the soils in the Chanoga AEA are characterized by an *ustic* soil moisture regime according to the Soil Taxonomy (Soil Survey Staff, 1975).

3.3 Geology and land forms

The geology of northern Botswana is characterized by the African Shield, present in the form of mainly granitoid gneisses of Precambrian age, belonging to the Basement Complex. The Basement Complex is overlain by the Ghanzi Formation, comprising sandstone, quartzite, shale and limestone of Late Precambrian to Early Cambrian age. A dolerite dyke swarm, formed in the Upper Jurassic, crosses the subsoil from southeast to northwest.

The underlying hardrock is covered by a package of medium to fine grained sands and silts forming the Kalahari Beds. This formation, which sediments are exposed to the surface, can reach a thickness of approximately 200m. The deposits are of aeolian, alluvial and lacustrine origin and form the parent material for the soils in the Chanoga AEA (data derived from the Geological Map of Botswana, Geological Survey Department, 1984).

The geomorphology of the study area is best described in terms of the prevailing land divisions and associated landforms (see Section 3.8 for the Land Unit Map, Figure 7 and the corresponding Table 9). The northern portion of the Chanoga AEA is covered by sandveld, consisting of parabolic dune remnants, surrounded by interdunal depressions and some minor pans. In the east, a lacustrine system belonging to the Makgadikgadi Pans area is found, comprising a fossil lagoon with a beach section, depressions and minor pans. The south is characterized by an alluvial system, belonging to the Boteti River. It contains a recent floodplain and a fossil floodplain, divided in higher parts, depressions and pans (with dimensions upto 1x2km).

No major relief differences are observed in the area; slopes vary between 0-5% and the entire AEA is situated at an altitude of approximately 930-950m asl. At places, probably due to minor faults in the underground, the northern bank of the Boteti River forms an escarpment of 10-15m down to the recent floodplain. Locally a terrace has been formed along the 100-400m wide floodplain.

3.4 Soils

3.4.1 Soil distribution and general characteristics

The soil information is compiled from the MAUN and TOTENG soil sheets (scale 1:250,000) and the accompanying report (Verbeek, 1989). Through aerial photography interpretation and additional field checks (60 augerings) almost all associations and complexes of the quarter-million soil sheets have been broken down into single soil units. Annex A is the Soil Map of the Chanoga AEA at scale 1:120,000.

The soils have been classified following the Revised Legend of the Soil map of the world (FAO, 1990). Reference is made to Table 3 in Section 3.4.2 for soil mapping unit codes and a correlation between the FAO 1990 Legend and the Revised Soil Legend of Botswana (Verbeek and Remmelzwaal, 1990). Table 9 in Section 3.8 reflects the soil types as components of the land units, while Appendix I provides a break down per land unit of the area occupied by each soil type (in hectare and as percentage of the land unit and of the AEA as a whole).

Generally, despite the differences in land division (sandveld, aeolian and lacustrine system) and in parent material, the same soils have developed on similar land forms. A total of 15 different soil types has been found, which form 16 soil mapping units. Most mapping units consist of a single soil unit; two complexes have been recognized, while Ferralic Arenosols are only found in a complex.

As Table 3 shows, Eutri-Haplic Arenosols are most frequently found in the Chanoga AEA. They occur on all higher positions, covering 33,652 ha (43% of the area). The complex of Areni-Haplic and Ferralic Arenosols, occurring on parabolic dune remnants covers 11,860 ha (15% of the area). The second most widespread soil is the Areni-Haplic Luvisol, mainly confined to depressions in the sandveld and the fossil floodplain, covering 15,695 ha (20% the area). The different Calcisols are covering 9434 ha in total (12% of the area) and occur mostly in depressions and pans throughout the area.

The general soil characteristics and distribution will be discussed below, according the land forms on which the soils occur (see the Land Unit Map, Figure 7 in Section 3.8).

Alluvial system

The recent floodplain of the Boteti River is characterized by poorly to imperfectly drained fine-medium to loamy sands with a moderate nutrient status (available phosphorus content of 5 ppm). These soils, which are regularly flooded, are classified as Areni-Eutric Fluvisols (mapping unit F1) and occupy 53% of the land unit. At places, silcrete banks outcrop in the floodplain and elsewhere silcrete stones and boulders are scattered over the river bed. The terraces along the floodplain are covered by a range of soils with textures varying from loamy sand to sandy clay and a somewhat restricted drainage: Luvi-Petric Calcisols (mapping unit C6), Eutric Gleysols (G1), Eutric Leptosols (LP1), Calci-Gleyic Luvisols (LV1) and Haplic Luvisols (LV2) are found.

The soils on the higher parts of the fossil floodplain have a coarse texture, a well to somewhat excessive drainage, a depth of > 1.25m and a poor nutrient status (available phosphorus levels of 2-3 ppm). The prevailing soil is classified as Eutri-Haplic Arenosol (mapping unit A1) and occupies 65% of the land unit. Eutri-Haplic Arenosols are also found in a complex (soils occurring at random on the same landform) with Luvic Arenosols (mapping unit A3, with a 50-50% distribution), covering 30% of the land unit.

The depressions in the fossil floodplain are characterized by soils with a calcic or a petrocalcic horizon in the subsoil and by soils lacking any concentration of carbonates. The former often have a restriction in depth and an available phosphorus content of 3 ppm, while the latter are deep and have a moderate nutrient status (available phosphorus content of 5 ppm). The first soils are classified as Areni-Haplic Calcisols (mapping unit C1), Areni- and Luvi-Petric Calcisols (C4 and C6, respectively) and the second as Areni-Haplic Luvisols (LV3). The Areni-Petric Calcisols cover 38%, and the Areni-Haplic Luvisols 37% of the land unit.

The soils in the pans are shallow to moderately deep and typified by a calcic horizon with a calcium carbonate equivalent of at least 40% (hypercalci-), which occurs within 50cm of the surface (epi-), with an underlaying petrocalcic horizon, at a depth of 50-100cm. The subsoil texture is sandy clayloam and the drainage class imperfectly. These soils are classified as Epi-Hypercalci-Luvi-Petric Calcisols (mapping unit C5).

Lacustrine system

The northern section of the fossil lagoon of the lacustrine system, consisting of a former beach, is entirely characterized by deep, somewhat excessively drained, grayish brown sands. The soils are classified as Eutri-Haplic Arenosols (mapping unit A1).

The southern portion of the fossil lagoon is typified by depressions and a few pans. The majority of the soils in the depressions are characterized by a texture ranging from fine sand to sandy clayloam, a slightly impeded drainage and the presence of a petrocalcic horizon, occurring between 50-100cm, at times severely limiting the soil depth. These soils are classified as Areni-Petric Calcisols (mapping unit C4) and (Epi-Hypercalci-) Luvi-Petric Calcisols (C5 and C6). Together the Calcisols occupy 58% of the land unit. The most common single soil unit are Areni-Haplic Luvisols (LV3), found at 42% of the land unit.

The (minor) pans are typified by very shallow soils (< 30cm deep) with a loamy sand texture and a petrocalcic horizon, classified as Petrocalci-Eutric Leptosols (LP1).

Sandveld

On the parabolic dune remnants in the sandveld, deep fine-medium sands with a low nutrient status (available phosphorus content of 2 ppm) and grayish- and yellowish brown colours are found. The dominant soils are classified as Eutri-Haplic Arenosols (mapping unit A1), occupying 68% of the land unit. In the entire northern section of the sandveld the Haplic Arenosols are found in a complex with Ferralic Arenosols (A4, with a 50-50% distribution), covering 32% of the dune tops.

Depressions in the northwest are characterized by fine-medium sands with clay lamellae or a gradual clay increase with depth of 3-6%. These soils are classified as (Lamelli-) Luvic Arenosols (mapping unit A2). Most depressions in the west and centre of the sandveld are typified by soils with a sandy topsoil and a subsoil texture varying from loamy fine sand to fine sandy loam. They are imperfectly to moderately well drained and have an available phosphorus content of 5 ppm and are classified as Areni-Haplic Luvisols (LV3). The Areni-Haplic Luvisols occupy 61% of the area of the depressions in the sandveld. In the east, calcic and petrocalcic horizons are frequently found in the soils in depressions, partly limiting the soil depth. The topsoils are often sandy, and sometimes a sodic phase occurs. These soils are classified as (Sodi-) Areni-Luvic Calcisols (mapping unit C3), Areni-Petric Calcisols (C4) and Luvi-Petric Calcisols (C6), together covering 25% of the land unit.

In the (minor) pans, imperfectly to moderately well drained soils with a sandy loam to sandy clayloam texture and a calcic horizon are found, at times having a sodic phase. These soils are classified as Luvic Calcisols (C2) and (Sodi-) Areni-Luvic Calcisols (C3), respectively. The former occupying 89% and the latter 11% of the land unit.

3.4.2 Soil attributes used in CYSLAMB and APSRAMB

The simulation models for crop growth (CYSLAMB) and for range biomass and livestock production (APSRAMB) require basic information on the soils of the study area.

The minimum (soil) dataset to run CYSLAMB consists of:

- the textural class of the topsoil (0-30cm)
- the drainage class
- the effective soil depth
- the available water holding capacity

The above soil attributes together with other characteristics can be found in Table 3.

Table 3. General soil characteristics

SOIL CHARACTERISTICS CHANOGA AGRICULTURAL EXTENSION AREA — TOTAL AREA: 78.295 ha

SMU a)	SOIL TYPES FAO 1990 name	FAO 1990 code	SLB 1990 b) code	SOIL DEPTH c) (m)	TEXTURE topsoil	TEXTURE subsoil d)	DRAINAGE CLASS e)	SOIL COLOUR moist subsoil	pH topsoil	AWHC (mm/m)	P (ppm)	AREA (ha)	AREA (%)
A1	Eutri–Haplic Arenosol	ARheu	A40, L16, LS17d, S17	> 1.25 (1.25)	coarse	FMS	SE	grayish brown	6.5	65	2	33652	43.0
A2	(Lamelli–)Luvic Arenosol	ARl	A41, S5b	> 1.25 (1.25)	coarse	FS	W	grayish brown to brown	6.2	70	3	3638	4.7
	Ferralic Arenosol	ARo	S3	> 1.25 (1.25)	coarse	FMS	SE	yellowish brown	6.1	65	2	f)	
A3	Eutri–Haplic and Luvic Arenosols	ARheu–ARl	A40–A41	as A1 and A2, ratio 50–50 %								2479	3.2
A4	Eutri–Haplic and Ferralic Arenosols	ARheu–ARo	A40–S3	as A1 and ARo, ratio 50–50 %								11860	15.2
C1	Areni–Haplic Calcisol	CLhar	L11	> 1.25 (1.25)	coarse	FS – LFS	MW – W	dark gray	8.4	75	2	415	0.5
C2	Luvic Calcisol	CLl	L24	> 1.25 (1.25)	medium	SCL	I	grayish brown to brown	6.4	130	3	529	0.7
C3	(Sodi–)Areni–Luvic Calcisol	CLlsoar	L24c	> 1.25 (1.25)	coarse	SL – SCL	I – MW	grayish brown to brown	7.0	125	3	2527	3.2
C4	Areni–Petric Calcisol	CLpar	A21a, L12, L12b	1.00 – 1.25 (1.00)	coarse	FS – LFS	MW – W	grayish brown	7.4	75	3	4245	5.4
C5	Epi–Hypercalci–Luvi–Petric Calcisol	CLpluephycal	C5b	0.50 – 1.00 (0.75)	medium	SCL	I	grayish brown to brown	6.8	130	3	736	0.9
C6	Luvi–Petric Calcisol	CLplu	A9b, L24b	1.00 – 1.25 (1.00)	medium	LFS – SCL	I – MW	grayish brown to brown	7.5	105	3	982	1.3
F1	Areni–Eutric Fluvisol	FLear	A24a	> 1.25 (1.25)	coarse	FMS – LS	P – I	grayish brown to white	5.7	75	5	843	1.1
G1	Eutric Gleysol	GLe	A31a	> 1.25 (1.25)	medium	SCL	P – I	black to grayish brown	6.3	130	5	21	0.0
LP1	Eutric Leptosol	LPe	C3, x g)	< 0.30 (0.30)	coarse	LS	P – I	grayish brown	7.2	80	3	258	0.3
LV1	Calci–Gleyic Luvisol	LVgcal	A7b	> 1.25 (1.25)	medium	SL – SC	I	dark gray to grayish brown	6.6	135	4	110	0.1
LV2	Haplic Luvisol	LVh	A14a	> 1.25 (1.25)	medium	SL – SCL	I – MW	dark gray to grayish brown	6.8	125	5	305	0.4
LV3	Areni–Haplic Luvisol	LVhar	A15a, L22a	> 1.25 (1.25)	coarse	LFS – FSL	I – MW	dark gray to grayish brown	6.6	100	5	15695	20.0

a) SMU – soil mapping unit
b) Revised Soil Legend of Botswana 1990
c) Value used in CYSLAMB between brackets
d) FMS – fine to medium sand, FS – fine sand, LS – loamy sand, LFS – loamy fine sand, SL – sandy loam, FSL – fine sandy loam, SCL – sandy clayloam, SC – sandy clay
e) SE – somewhat excessively, W – well, MW – moderately well, I – imperfectly, P – poorly
f) This soil type only occurs in complex with unit A1
g) The LPe is not recognised by the SLB 1990 in an environment of alluvial parent material.

The minimum (soil) dataset to run APSRAMB consists of:

- the textural class of the topsoil (0-30cm)
- the effective soil depth
- the available phosphorus content (0-25cm)
- fraction of coarse fragments
- the infiltration rate (mm/hr)
- Vossen's soil moisture reserve, Mm (mm)
- Vossen's constants A, B, C
- the moisture content at field capacity, FC
- the moisture content at wilting point, WP
- soil moisture content when air dry (mm/mm)

The first three soil attributes can be found in Table 3, the fraction of coarse fragments is 0% for all soils in the study area and the remaining parameters are reflected in Table 4.

Table 4. Additional soil characteristics to run APSRAMB

SMU	SOIL TYPE	INFILTRATION (mm/hr)	VOSSEN Mm (mm)	VOSSEN A	VOSSEN B	VOSSEN C	SOIL MOISTURE FC (mm/mm)	SOIL MOISTURE WP (mm/mm)	SOIL MOISTURE air dry (mm/mm)
A1	ARheu	350	95.0	0.02	0.28	3.0	0.110	0.045	0.015
A2	ARl	250	107.0	0.02	0.28	3.0	0.123	0.048	0.016
	ARo	400	107.0	0.02	0.28	3.0	0.123	0.048	0.016
C1	CLhar	100	107.0	0.02	0.28	3.0	0.123	0.048	0.016
C2	CLl	50	212.3	0.02	0.22	1.0	0.254	0.125	0.042
C3	CLlsoar	50	212.3	0.02	0.22	1.0	0.254	0.125	0.042
C4	CLpar	100	129.3	0.02	0.28	3.0	0.152	0.068	0.023
C5	CLpluephypcal	100	267.7	0.02	0.16	0.2	0.333	0.196	0.065
C6	CLplu	100	267.7	0.02	0.16	0.2	0.333	0.196	0.065
F1	FLear	250	129.3	0.02	0.28	3.0	0.152	0.068	0.023
G1	GLe	20	267.7	0.02	0.16	0.2	0.333	0.196	0.065
LP1	LPe	150	212.3	0.02	0.22	1.0	0.254	0.125	0.042
LV1	LVgcal	50	350.0	0.02	0.16	0.2	0.450	0.300	0.100
LV2	LVh	50	267.7	0.02	0.16	0.2	0.333	0.196	0.065
LV3	LVhar	150	129.3	0.02	0.28	3.0	0.152	0.068	0.023

N.B.: See Table 3 for a description of the Soil Types.

The characteristics given in Table 3 represent the modal form of the soil types, based on typical profiles from Ngamiland stored in the Botswana Soil Database (BSD). The infiltration rates given in Table 4, have been calculated from data from the BSD, while Vossen's soil moisture reserve Mm and the moisture contents at field capacity, wilting point and air dry have been calculated based on data from the BSD for the reference soils used in the Map of Land Suitability for Crop Production (Radcliffe *et al.*, 1992). The Vossen constants A, B, C are given in Vossen (1990).

3.4.3 Soil degradation

The World Map of the Status of Human-induced Soil Degradation (Oldeman *et al*, 1990) describes a method for the assessment of soil degradation. Soil degradation is defined by the type and the severity of the degradation. The severity is determined by the degree of the degradation and the percentage of the mapping unit affected. The below description of the soil degradation is also based on the proposals done in the *Guidelines for Agricultural Land Use Planning in Botswana* (LUPSAD Working Group, 1995).

Due to the lack of relief, no water erosion of any significance has been observed, and as a consequence no erosion assessment with the SLEMSA model has been carried out. However, wind erosion, chemical deterioration (nutrient depletion) and physical deterioration (loss of topsoil structure) do occur. The observed phenomena of human-induced soil degradation are mainly confined to the fossil floodplain and the southern part of the sandveld.

Areas most prone to wind erosion are those with a sparse vegetation cover and topsoils of fine sand to sandy loam texture, particularly farmers' fields. Strong winds normally precede the cropping season, and redistribute topsoil particles. Often wind ripples have formed on the surface. But even after planting, wind erosion and deposition can severely hamper a proper germination of seeds (Bekker, 1995). The wind erosion observed is of a low severity; the degree can vary from light to moderate, but the area affected is generally small, < 5% of the concerned soil mapping units. At places the productivity of the land has greatly be reduced; land improvements, however, could restore the productivity.

Nutrient depletion and the loss of topsoil structure of farmers' fields are yearly recurring phenomena. The mainly sandy soils are low in nutrients (organic matter content of < 1% and available phosphorus levels of 2-5 ppm) and have a weak topsoil structure. Farmers undertake little to restore the structure or to replenish the nutrients taken up by their crops. This deterioration is of a low severity; the degree of severity of the degradation is light. The agricultural potential of the land units affected is slightly reduced, but restoration to full productivity is still possible.

As the above described soil degradation features are only observed at some places in the study area, no detailed inventory has been carried out and no mention has been made in Table 3, describing the soil characteristics.

3.5 Water resources

As surface- or groundwater availability is a crucial requirement for non-rainfed agricultural activities, such as horticulture, extensive grazing, and intensive animal based enterprises, an inventory was made of existing water points in the Chanoga AEA. See Figure 4 for a Water Point Map.

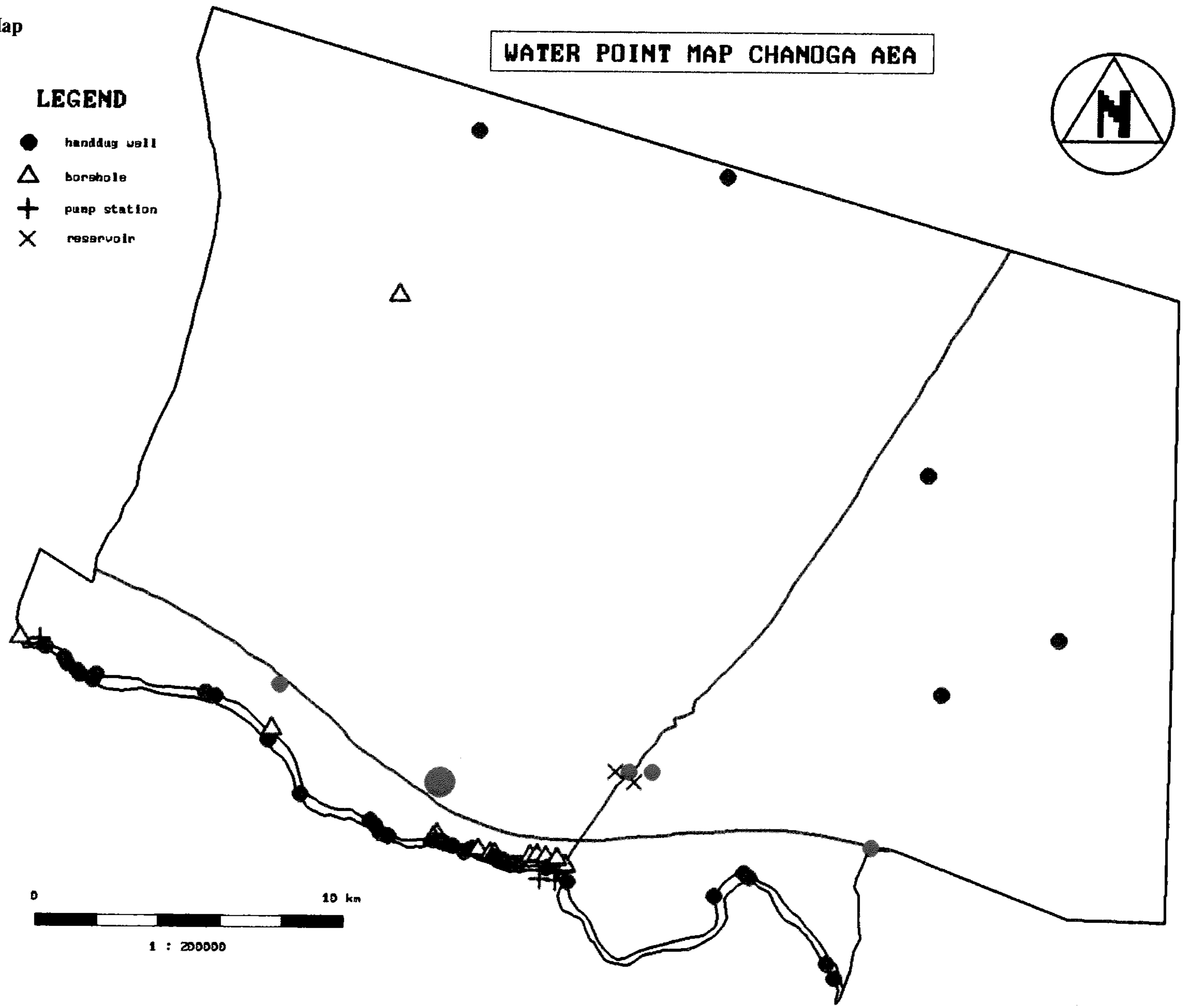
The southern boundary of the Chanoga AEA is formed by the Boteti River. This stream is fed by the Thamalakane River, which is the main collector of water that drains the eastern part of the Okavango Delta. The Thamalakane, as the Boteti River, does not have a permanent nature and its water supply relies on the outflow of the Okavango Delta and indirectly on the rains in the Angolan highlands, which form the catchment area of the Okavango Delta.

Wilson and Dincer (1976) drafted a water balance for the Okavango system (see Table 5). From the total inflow and recharge by rainfall, approximately 95% evapotranspires via open water evaporation and transpiration by (semi-)aquatic plants. Less than 2% recharges aquifers in the Kalahari Beds via percolation through the sediments and along neo-tectonic fractures. Less than 2% drains out of the Okavango Delta. The Thamalakane River collects water from the main Delta outlet channels and runs along the equally named fault line in southwestern direction to the junction with the Nhabe and the Boteti River. In seasons with a high flood and sufficient rainfall, part of the water will reach Lake Ngami through the Nhabe River and part will flow via the Boteti River past Chanoga, Makalamabedi to Rakops and Mopipi, to finally end in the Makgadikgadi Pan system.

Table 5. Tentative water balance for the Okavango System (after Wilson and Dincer, 1976)

INFLOW (Okavango River)	11 X 10^9 m^3/yr	**EVAPOTRANSPIRATION** (Okavango Swamps)	15.4 x 10^9 m^3/yr
PRECIPITATION (Okavango Delta)	5 x 10^9 m^3/yr	**OUTFLOW** (Boteti River)	0.3 x 10^9 m^3/yr
		GROUNDWATER RECHARGE (Okavango aquifers)	0.3 x 10^9 m^3/yr
	16 x 10^9 m^3/yr		16 x 10^9 m^3/yr

Figure 4. Water Point Map
Chanoga AEA



No water has been flowing in the Boteti River past the Chanoga AEA since 1992. The last large pools dried up around mid 1995. A situation without surface water remained. No dams or reservoirs to harvest rain or flood waters are constructed in the area. Temporary pools of rain water are found in most of the depressions and pans in the planning area, during the months of December-March.

Approximately 200 shallow (< 2m) to moderately deep (2-6m) hand dug wells have been observed in the centre of the Boteti River floodplain, see Figure 4. Most of the wellpoints are concentrated close to the settlements of Samedupi (30), Mawana (35), Chanoga (80) and Xhana (60). The wellpoints have been dug and are owned by people of the mentioned villages. The majority yields fresh water and is in use to provide drinking water for the villagers and to water livestock. During and after the months of the field surveys (first half of 1995), water levels in the wellpoints were dropping considerably. Wells located close to the escarpment showed a high water level (close to the surface) and are most probably fed by seepage from the sandveld. Wells further away from the river bank usually had a more shallow water level.

Boreholes stored in the Ngamiland Waterpoint Survey Database have been checked. Several are located on the northern bank of the Boteti River. One supplies the village of Chanoga with water, pumped up from 21m deep with a diesel engine. Two others yield water, that is pumped to the Shorobe Quarantine Camp, through a pipeline of approximately 45km and is transported by water bowser to Maun to supplement the town water shortage. Another eight boreholes are located in private yards and used for domestic consumption and/or vegetable gardens.

Six cattleposts located in the middle and in the north of the planning area, along the old Francistown road have all access to hand dug wells. Water is pumped up with diesel engines from around 30-40m depth. The quality is slightly salty, but acceptable for livestock watering. These hand dug wells are owned by the cattlepost owners and at times shared with farmers, who track their cattle to the Shorobe Quarantine Camp.

The Hydrogeological Map of the Republic of Botswana, sheets 1 and 4 (Neumann-Redlin, 1982 and Dechend, 1980, respectively) shows variable poor to fair groundwater development prospects for the planning area. Productive aquifers may be found in the sediments and rocks belonging to the Kalahari Beds. The map indicates a gradient in contour lines of the piezometric surface from 30m below the land surface in the northeast to < 20m below the land surface in the southwest of the Chanoga AEA. This gradient is accompanied by a groundwater flow in the same direction, towards the Boteti River. Groundwater can be struck at depths greater than the piezometric surface.

The Hydrogeological Map reflects several known boreholes and wellpoints in the planning area, with moderately saline (TDS content 5,000-10,000 mg/l) to very saline (TDS content ≥ 10,000 mg/l) groundwater. The wellpoints dug at the cattleposts in the northern part of the planning area confirm the contour lines and the water quality indicated on the map.

Table 9 in Section 3.8 reflects the water situation in the different land units.

3.6 Vegetation

3.6.1 Distribution of vegetation types

The vegetation characterization of the study area was done through the interpretation of aerial photography complemented with 31 field observations. Annex B is the Vegetation Map of the Chanoga AEA at scale 1:120,000.

A total of 11 vegetation units (see Table 6) was defined manually and their species information stored in the Botswana Vegetation Database. Each vegetation unit is typified by a combination of prominent species and its structure, which is derived from the canopy cover from the separate strata.

A maximum of four prominent species, i.e. species with the highest occurrence and the highest cover percentages from the species present in all observations belonging to one vegetation unit, is chosen to characterize each unit. A table showing the occurrence and cover percentages from all species found in each vegetation stratum in each unit is given in Appendix II. Five different strata are recognized: tree > 3m, upper bush 1.5-3m, lower bush < 1.5m, herbs under canopy and herbs away from canopy. During the survey, the canopy cover of each separate stratum was estimated, as well as the total site cover (allowing for overlapping strata).

In the remainder of this section a brief description is given from each vegetation type, focussing on its structure, prominent species, strata canopy coverage and distribution. This information is summarized in Table 6. For the relationships (areas covered) between vegetation types, soils and land units reference is made to the Land Unit Map, Figure 7, Table 9 in Section 3.8 and Appendix IV.

Unit V1 consists of grassland, solely typified by reeds of the species *Phragmites australis* with a coverage of 85%. This unit occurs in concentrated patches in the centre of the floodplain of the Boteti River on Areni-Eutric Fluvisols and occupies only 259 ha.

Unit V2 consists of grass/forbland, characterized by *Cynodon dactylon* (25% cover), *Juncus* spp. (25%) and sedges with a total canopy cover of 60%. The unit is found in the floodplain on Areni-Eutric Fluvisols and on the terraces along the Boteti River and occupies 667 ha.

Unit V3 consists of grass/forbland with clumps of open savanna, with a total site canopy coverage of 10%. The herbs have not been identified, while the open savanna is typified by *Acacia mellifera* and *A. tortilis*. This unit is present in the pans of the fossil floodplain, occupying 359 ha and predominantly related to Epi-Hypercalci-Luvi-Petric Calcisols.

Unit V4 consists of (dense) shrub savanna with *Lonchocarpus nelsii*, *Terminalia sericea*, *Bauhimia petersiana* and *Commiphera pyracanthoides* as prominent species and a total canopy cover of 39%. The first two species are, in this region, indicative for deep sandy soils. This vegetation type is characterized by a good grass cover of 11% and 28% under and away from canopy, respectively. The principal grasses species are *Digitaria milanjiana*, *Eragrostis lehmanniana*, *Schmidtia pappophoroides* and *Stipagrostis uniplumis*. This unit is the most common, covering 37,744 ha or 48.2% of the study area, and is mainly found on Eutri-Haplic and Ferralic Arenosols of the parabolic dune remnants in the Sandveld and on the beach of the fossil lagoon in the Lacustrine System.

Unit V5 consists of dense shrub savanna typified by *Colophospermum mopane* and *Grewia* spp., with a total canopy coverage of 39%. The herbaceous strata under and away from canopy cover 15% and 32%, respectively. The main species are *Stipagrostis uniplumis*, *Urochloa trichopis* and *Eragrostis rigidor*. This unit mostly occurs in depressions in the Sandveld on Areni-Haplic Luvisols and occupies 1493 ha.

Unit V6 consists of dense shrub savanna and savanna characterized by the species *Acacia tortilis*, *Catophractes alexandri* and *Combretum imberbe*, with an average site canopy cover of 46%. This last species often indicates the presence of fresh groundwater and is frequently found in the vicinity of hand dug wells or boreholes at cattleposts. The unit V6 mainly occurs in the depressions in the Sandveld, often on Luvic Arenosols and covers 4481 ha. The herbaceous strata cover 5% and 12%, respectively, with as main species *Eragrostis* spp., *Schmidtia pappophoroides*, *Stipagrostis uniplumis*, and *Urochloa trichopis*.

Unit V7 consists of a savanna with as prominent species *Terminalia prunioides*, and *Acacia tortilis*, with a total site canopy cover of 30%. This unit is found in the depressions and pans of the fossil floodplain. The herbaceous layers are moderately well established, with covers of 11% (under) and 21% (away from canopy) and the main species are *Panicum maximum*, *Digitaria milanjiana*, *Urochloa trichopis* and *Stipagrostis uniplumis*. *Terminalia prunioides* is an indicator species for a petrocalcic horizon in the soil. Hence, the unit (covering 1646 ha) is above all found on Calcisols.

Table 6. Vegetation characteristics

VEGETATION CHARACTERISTICS CHANOGA AGRICULTURAL EXTENSION AREA — TOTAL AREA: 78.295 ha

VEGETATION UNIT	AREA (ha)	AREA (%)	PROMINANT SPECIES	STRUCTURE	CANOPY COVER (%) SITE	TREE	BUSH1	BUSH2	HERB1	HERB2	LAND UNITS	SOIL TYPES
V1	259	0.3	*Phragmites australis*	GR						85	AS1	FLear
V2	667	0.8	*Cynodon dactylon, Juncus spp., sedges*	GR/FL						60	AS1	CLplu, FLear
V3	359	0.5	*grasses and forbes, Acacia mellifera, A. tortilis*	GR/FL + SAO	10	3	7	3		14	AS4	CLpluephycal, CLlsoar
V4	37744	48.2	*Lonchocarpus nelsii, Terminelia sericea, Bauhimia petersiana, Commiphera pyracanthoides*	SS–SSD	39	5	9	28	11	28	LS1, SV1/2/3	ARheu, ARheu–ARo, CLpar, LVhar
V5	1493	1.9	*Colophospermum mopane, Grewia spp.*	SSD	39	5	7	32	15	32	SV2	ARheu–ARo, LVhar
V6	4481	5.7	*Acacia tortilis, Catophractes alexandri, Combretum imberbe*	SSD–SAD	46	7	12	37	5	12	LS2/3, SV2/3	ARheu–ARo, ARl, CLpar
V7	1646	2.1	*Terminelia prunioides, Acacia tortilis*	SA	30	16	11	20	11	21	AS2/3/4	ARheu, CLhar, CLpar, CLpluephycal, LVhar
V8	17079	21.8	*Acacia erubescens, A. leuderitzii, Boscia albitrunca*	SA–SAD	31	18	8	11	5	11	AS2/3/4, LS2, SV1/2/3	ARheu, CLlsoar, CLpar, LVhar
V9	10929	14.0	*Albizia anthelmintica, Acacia erioloba, A. erubescens, Lonchocarpus nelsii*	SAD	38	15	12	20	12	13	AS1/2/3, LS1/2, SV1/2	ARheu, ARheu–ARl, LVhar
V10	2710	3.5	*Colophospermum mopane, Lonchocarpus nelsii, Terminelia sericea*	SAD	41	15	13	21	1	13	SV1	ARheu–ARo, ARl
V11	928	1.2	*Berchemia discolor, Combretum imberbe, Croton megalobotrys, Sansevieria sp.*	W	43	21	14	21	13	6	AS1/3	ARheu, ARheu–ARl, CLpar, CLplu, LVh

N.B.: Not listed are the land units, on which vegetation units occupy less than 5 % of the land unit. Similarly not listed are soil units, occupying less than 5 % of the respective vegetation unit.
See Tables 3 and 9 for an explanation of the Soil Type and the Land Unit codes.

STRUCTURE CODES: GR – grassland, FL – forbland, SS – shrub savanna, SSD – dense shrub savanna, SAO – open savanna, SA – savanna, SAD – dense savanna, W – woodland

Unit V8 consists of a (dense) savanna typified by *Acacia erubescens*, *A. leuderitzii* and *Boscia albitrunca*, with an average site canopy coverage of 31%. This vegetation type has a wide range of habitats, but is mainly found in all depressions of the Alluvial and Lacustrine System and the Sandveld. It occurs on Areni-Haplic Luvisols, Calcisols and Eutri-Haplic Arenosols and covers 17,079 ha, being the second most widespread unit with 21.8% of the AEA. The herbaceous layers cover 5% and 11%, respectively, with as most prominent grass species *Eragrostis* spp., *Urochloa trichopis*, *Panicum maximum* and *Schmidtia pappophoroides*.

Unit V9 consists of a dense savanna characterized by *Albizia anthelmintica*, *Acacia erioloba*, *A. erubescens* and *Lonchocarpus nelsii*, having an average site canopy cover of 38%. The herbaceous layers under and away from canopy reach an average coverage of 12% and 13%, respectively, with *Schmidtia pappophoroides* and *Panicum maximum* as dominant species. This unit covers 10,929 ha (14% of the area) and is mostly present on the higher parts of the fossil floodplain and on parabolic dune remnants, related to Eutri-Haplic and Luvic Arenosols.

Unit V10 consists of a dense savanna with *Colophospermum mopane* (both trees and shrubs, in each layer covering approximately 15%), *Lonchocarpus nelsii* and *Terminalia sericea*, with total site canopy coverage of 41%. Hardly any herbs occur under the canopy (1% cover), which is typical for vegetation types with *Colophospermum mopane* trees. Away from canopy a coverage of 13% is reached, mainly by *Stipagrostis uniplumis*. This vegetation type is confined to the northwestern corner of the study area. It covers 2710 ha, and is mostly found on parabolic dune remnants of the Sandveld on Eutri-Haplic and Ferralic Arenosols.

Unit V11 consists of woodland with as prominent species *Berchemia discolor*, *Combretum imberbe*, *Croton megalobotrys* and *Sansevieria* sp.. The unit has an average site canopy cover of 43% and relatively high tree and upper bush layer covers of 21% and 14%, respectively. The herbaceous layers cover 13% (under) and 6% (away from canopy), respectively. The most common grasses are *Panicum* spp., *Eragrostis* spp. and *Chloris virgata*. This woodland is restricted to a narrow fringe (usually less than 500m wide) along the Boteti River and is often referred to as "riverine" or "riperian" woodland. It occurs at the edge of the higher parts of the fossil floodplain, marking the escarpment down into the actual river valley. It only covers 928 ha and is found on a wide range of soils.

3.6.2 Vegetation characteristics used in APSRAMB

The animal production and range assessment model for Botswana (APSRAMB) requires data on the canopy cover and the species composition of the different strata of each vegetation type. This information, recorded in the field, has been stored in the Botswana Vegetation Database. Table 6 gives a summary of the prominent species, the structure and the canopy cover of the different strata of each vegetation type. Furthermore, Table 6 shows the vegetation units in relation to the main land units and soil types on which they occur.

The occurrence (in percentage cover) of all species per stratum for each vegetation type is listed in Appendix II. From this table the most frequently occurring species per vegetation unit, have been chosen as prominent species to characterize each unit. Appendix III gives a detailed break down per vegetation unit of the area occupied by each soil type (in hectare and as percentage of the vegetation unit and of the entire AEA). This information, the weighting of the soil units according their extent by vegetation unit, is used by APSRAMB to calculate the biomass production.

Additionally the model needs information for each vegetation unit on the average rooting depth of the herbaceous species and the average digestibility of fodder per month. The first parameter is estimated, based on dominant grass species and the depth of the soils in each vegetation unit. The second is related to the species composition of the strata in each vegetation unit. The values used for the above mentioned parameters for each vegetation type are shown in Table 7.

Table 7. **Additional vegetation characteristics to run APSRAMB**

VEGETATION UNIT	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
root depth (mm)	800	800	450	550	550	550	550	550	550	550	550
digestability JAN 1)	0.208	0.293	0.293	0.543	0.585	0.439	0.585	0.439	0.409	0.585	0.437
digestability FEB	0.211	0.257	0.257	0.476	0.513	0.385	0.513	0.385	0.361	0.513	0.390
digestability MAR	0.229	0.255	0.255	0.473	0.509	0.382	0.509	0.382	0.358	0.509	0.386
digestability APR	0.246	0.240	0.240	0.446	0.480	0.360	0.480	0.360	0.338	0.480	0.366
digestability MAY	0.264	0.232	0.232	0.430	0.463	0.347	0.463	0.347	0.326	0.463	0.354
digestability JUN	0.243	0.210	0.210	0.390	0.420	0.315	0.420	0.315	0.295	0.420	0.318
digestability JUL	0.209	0.250	0.250	0.464	0.500	0.375	0.500	0.375	0.349	0.500	0.372
digestability AUG	0.198	0.185	0.185	0.344	0.370	0.278	0.370	0.278	0.261	0.370	0.284
digestability SEP	0.191	0.180	0.180	0.344	0.360	0.270	0.360	0.270	0.255	0.360	0.279
digestability OCT	0.237	0.190	0.190	0.353	0.380	0.285	0.380	0.285	0.270	0.380	0.300
digestability NOV	0.202	0.190	0.190	0.353	0.380	0.285	0.380	0.285	0.271	0.380	0.302
digestability DEC	0.236	0.300	0.300	0.557	0.600	0.450	0.600	0.450	0.420	0.600	0.449

1) x 100 %

3.6.3 Veld products

The most commonly collected veld product are discussed in this section. A small distribution map (scale 1:500,000) is given based on the respective combination of land forms and vegetation units.

Fishing

When the Boteti River is flooded fishing is practiced regularly. Fish, mainly bream, is a supplement to the family diet and is sold in the village.

Mogwana and moretlwa

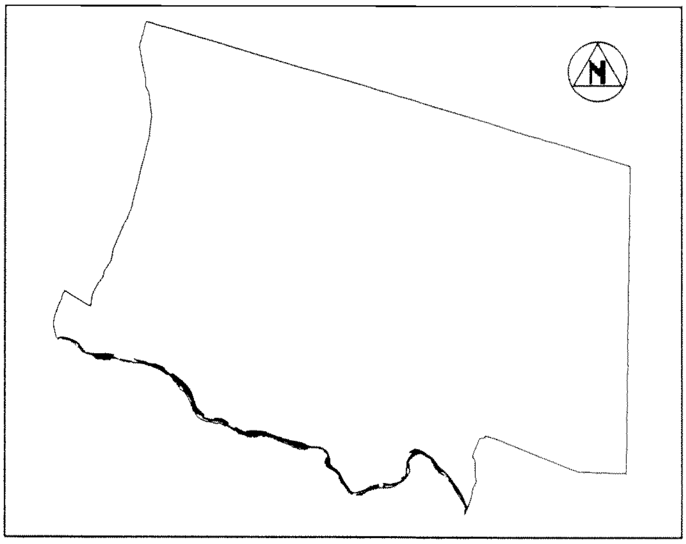
Almost throughout the study area (except for the riverine fringe, the pans and the mopane tree dominated area), the shrubs of *Grewia flavescens* 'mogwana' and *G. flava* 'moretlwa' are found and their fruits collected. The berries are eaten as sweets and are used for the brewing of 'khadi', traditional beer.

Tswii and mothebe

Tubers of the waterlily *Nymphaea* sp. 'tswii' are frequently collected, when available. The tubers are cooked and eaten.

The sedge 'mothebe', found on the higher portions of the actual floodplain and the adjacent terraces and occurring in vegetation unit V2, is used in the construction of roofs of traditional huts.

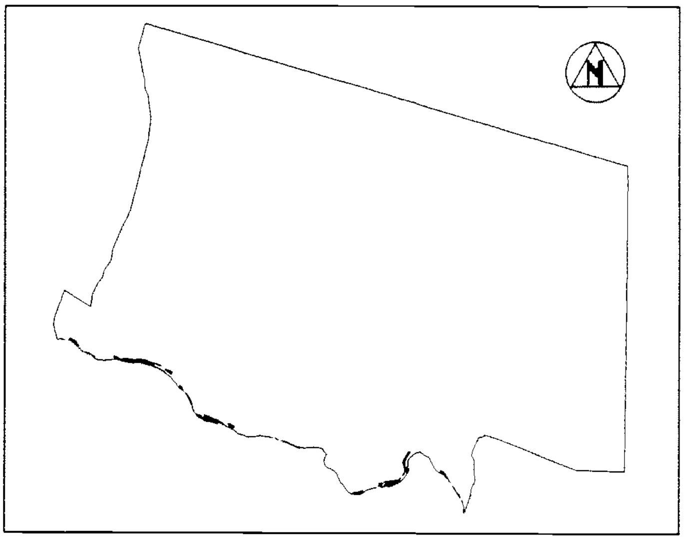
Figure 5a. **Tswii, *Nymphaea* sp. and mothebe**



Lethaka

Reeds of the species *Phragmites australis*, better known as 'lethaka', grow in clusters in the center of the river floodplain and have been mapped as vegetation unit V1. These reeds are harvested and used for traditional hut construction, fencing off of enclosures around huts or entire compounds. Once flattened, the reed stems are woven into mats, called 'mabinda'. These mats can be used on floor, walls or ceilings. Lethaka is often sold in villages.

Figure 5b. **Lethaka, *Phragmites australis***



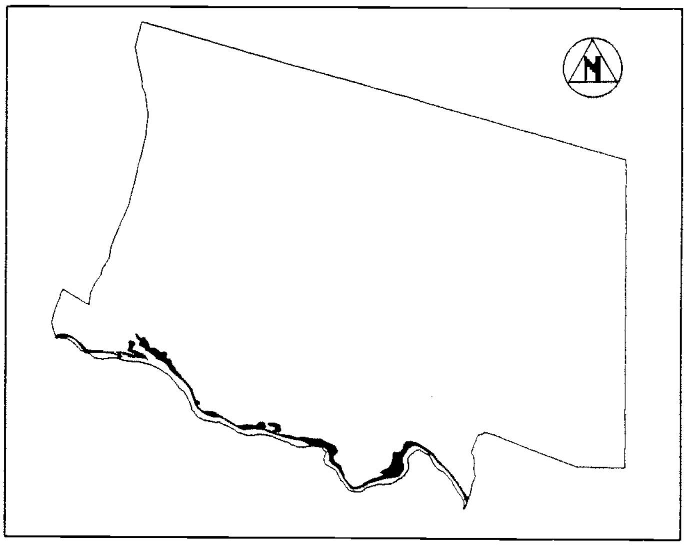
Mokola palm, motsintsila, *Sansevieria*

In the vegetation unit V11, along the Boteti river, the following species are found: *Hyphaene petersiana*, 'mokola' palms, which leaves are used for basket weaving.

Berchemia discolor, 'motsintsila', of which the berries are eaten as sweets.

Sansevieria sp., of which the fibers are used as a kind of tying rope.

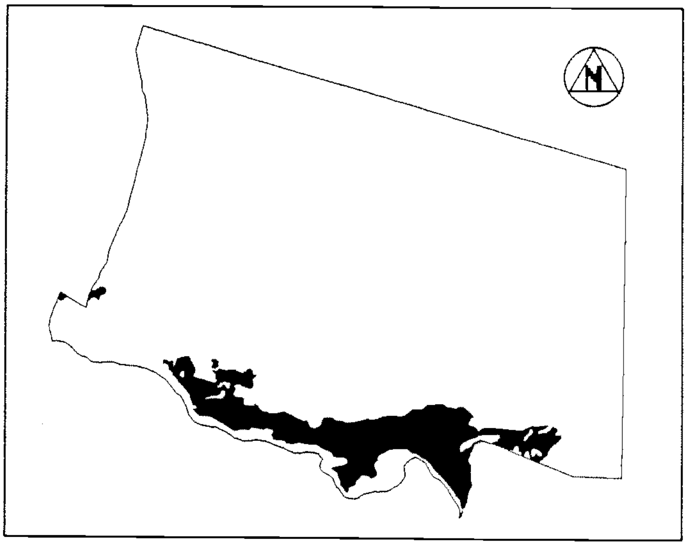
Figure 5c. **Mokola palm, *Hyphaene petersiana*, motsintsila, *Berchemia discolor*, *Sansevieria* sp.**



Rothwe

The wild spinach *Cleome gynandra*, 'rothwe,' mainly occurs on the higher part of the fossil floodplain in the vegetation unit V9. It is regularly collected for home consumption and for sales during the months of December - March.

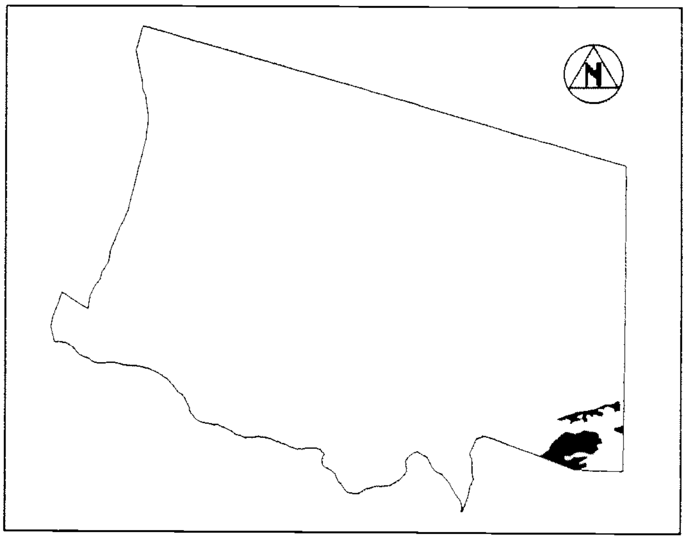
Figure 5d. **Rothwe, *Cleome gynandra***



Sengaparile

Devil's claw, *Harpagophytum procumbens*, 'sengaparile' or 'grapple plant', occurs on the beach sands of the fossil lagoon in vegetation unit V9. During the farm interviews, none of the interviewees mentioned the harvest of this traditional medicinal herb. It is probably only used locally.

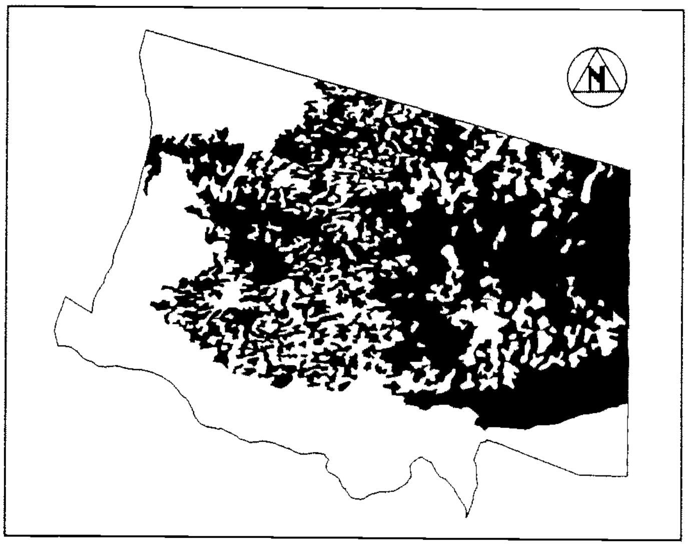
Figure 5e. Sengaparile, *Harpagophytum procumbens*



Thatching grass

Most thatching grass used in the area is cut on the dune remnant and in the depressions of the Sandveld and on the beach of the fossil lagoon, in both cases in vegetation unit V4. Although not confirmed, the most likely species to be used are: *Digitaria milanjiana*, *Stipagrostis uniplumis* and *Eragrostis lehmanniana*.

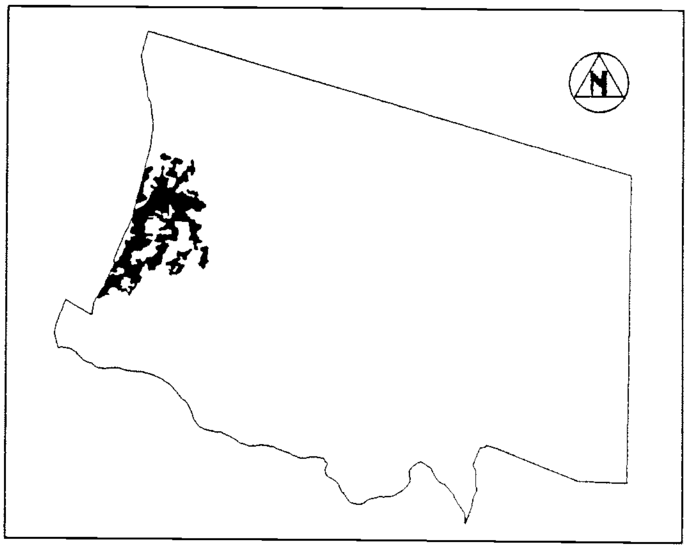
Figure 5f. Thatching grass



Morotologwa

The berries of *Ximenia americana*, 'morotologwa', are regularly collected and eaten as sweets. They are found in vegetation unit V9 on the remnants of the parabolic dunes.

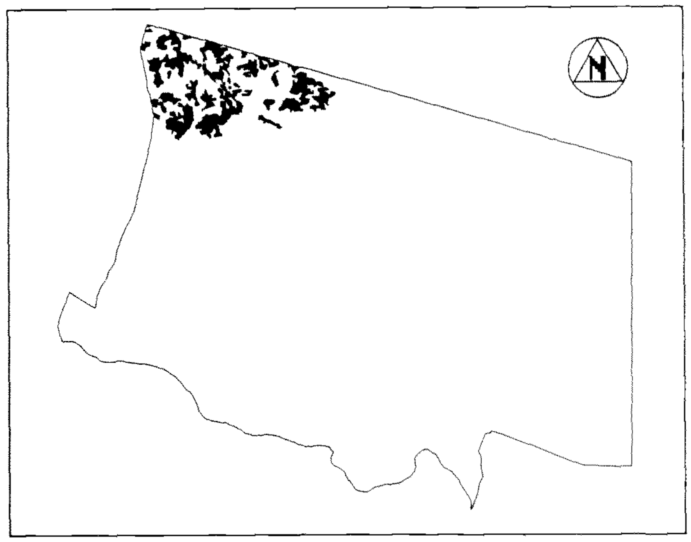
Figure 5g. Morotologwa, *Ximenia americana*



Mopane

Logs of *Colophospermum mopane*, 'mopane' trees are frequently used for construction purposes and as fuelwood. They are found in the northwestern corner of the area on the dune remnants, in vegetation unit V10.

Figure 5h. Mopane, *Colophospermum mopane*



3.6.4 Range degradation

Range degradation in the form of a reduced herbaceous cover, both under and away from canopy has been observed on the higher parts of the fossil floodplain. In a zone with a width of approximately 3-5km bordering the Boteti River, a linear gradient of degradation was noticed. The closer to the river, the poorer the quality of the range. This phenomenon is strongly related to the increased grazing pressure from cattle and smallstock that is watered from wells in the riverbed.

Around cattleposts a similar situation, but in a pattern of concentric circles, is found. Closest to the kraals and boreholes the range has been overgrazed and further away in the sandveld, it seems in equilibrium with the livestock and wildlife, that utilizes it.

3.7 Present land use

The major land uses in the Chanoga AEA are arable farming, livestock production, village/settlements and the collection of veld products. See Section 3.6.3 for maps with the occurrence of the main veld products and Table 8 below for the extent of the first three land uses.

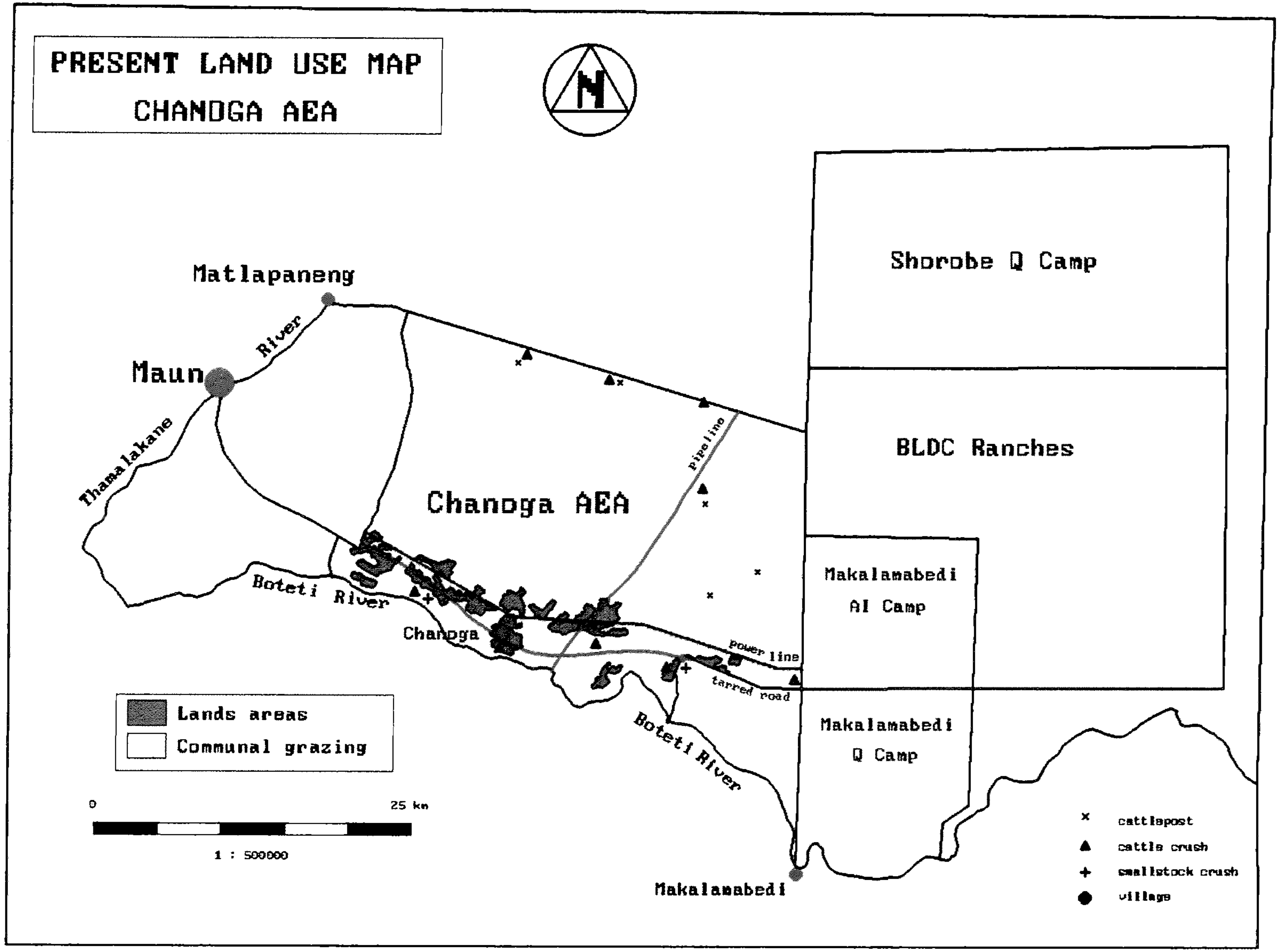
Table 8. Extent of major present land uses

LAND USE	AREA	
	(ha)	(% of AEA)
Arable farming, rainfed (lands areas)	1,545	2
Livestock production, extensive grazing (around villages and cattleposts)	76,000	97
Village/settlements	750	1

The lands area of 1,545 ha is based on the baseline area, calculated from 1990/1991 ARAP records, provided by the AD. This is a reliable approximation, as the entire demarcated field of each farmer was measured for drought relief purposes during that season. The actual area ploughed usually forms only a portion of the whole field.

The total extent of settlements is estimated at 750 ha, using a Landsat TM image (1994). The remainder is grazing area between the fields and is added to the total figure for communal grazing land amounting 76,000 ha, see Present Land Use Map, Figure 6.

Figure 6. Present Land Use Map



3.7.1 Arable farming

The given extent for arable farming accounts for the area used for rainfed farming. Most fields are found on Hapli-Eutric Arenosols (higher parts of the fossil floodplain) of the alluvial system and on the Hapli-Eutric Arenosols (dune remnants) and the Areni-Haplic Luvisols (depressions) of the southern portion of the sandveld.

Molapo farming, flood recession farming, is practiced in years of high floods in the Boteti River. Many dilapidated fences around former molapo-field have been observed.

The lands area, indicated on the Present Land Use Map Figure 6, consists of rainfed arable fields, which are concentrated in zones near the settlements. Often the fields are not bordering each other, thus leaving natural vegetation for grazing.

In Section 4.4.3.1 a detailed description is given of the crop related production systems.

3.7.2 Livestock production

The livestock production in the Chanoga AEA is based on extensive grazing. Three types of livestock rearing have been observed. Most farmers graze there cattle around the settlements and in the sandveld just north of the villages and water the animals in wellpoints in the Boteti River. Goats are normally kept close to the homesteads.

A small amount of cattleposts is located in the centre and the north of the sandveld, see figure 6. Cattle is grazed freely around the cattleposts and normally watered there and at times in the Boteti River or the Thamalakane River (to the west). Smallstock is generally kept close to the cattleposts.

The Present Land Use map indicates the location of cattle crushes and smallstock crushes/diptanks. Two syndicates in Mawana and Xhana have developed the latter. The cattle crushes are situated outside the settlements and near most of the cattleposts.

In Section 4.4.3.4 a detailed description is given of the animal related production systems.

3.7.3 Miscellaneous land uses

The Chanoga AEA comprises the settlement of Mawana in the west, the village of Chanoga and the settlement of Tsibogolamatebele in the centre and the settlement of Xhana in the east, see Figure 6.

Also indicated on the Present Land Use Map are some infrastructural features. The new tarred Nata-Maun road meanders from east to west trough the southern portion of the area. A couple of kilometers north the straight alignment of the powerline, that connects Maun with the national grid, is found sub-parallel to the main road. Cutting across from the Boteti River to the northeast is a track running along the pipeline, which is used by the Veterinary Department to pump water to the Shorobe Quarantine Camp.

Not reflected on the map, due to technical reasons or too small a scale are a number of other land uses.

The eastern, northern and western boundaries of the AEA are formed by sand tracks.

A horticulture project near Samedupi along the Boteti River was (temporarily) closed down in 1993, due to a lack of water in the river.

East of Chanoga nine large residential plots are situated. These plots have been developed with houses, boreholes and gardens. One contains a large citrus orchard.

Amidst the above mentioned residential plots, the Xyga Fishing Camp is located. This recreational enterprise rents out accommodation. The business is presumably suffering from a lack of water in the river.

The National Museum has identified some sites of archeological importance (oral comm.). Signs of prehistoric inhabitation and the discovery of stone tools like scrapers and arrow points have been reported. The exact locations are not known.

The entire Chanoga AEA falls in the controlled hunting area NG35. NG35 stretches from the Veterinary Cordon Fence north of Shorobe to the Boteti and Nhabe Rivers and is confined by the Buffalo Fence in the west and the fence and cutlines bordering the Makalamabedi and Shorobe Quarantine Camps in the east. This area is designated for citizen hunting since 1995. See Section 6.6 for details on hunting quota and financial returns.

3.8 Land Units

In order to present all previously discussed data on natural resources and for land evaluation purposes the concept of land unit is introduced. Land units are basic spatial units, which are relatively homogeneous with respect to their resource base and can be mapped individually.

Based on major land divisions and land forms, 10 land units have been identified in the Chanoga AEA, see Figure 7 for the Land Unit Map. Each land unit is further typified by data on the dominant slope, soil type and degradation, water situation, vegetation units and dominant present land use, see Table 9 for characteristics of the land units.

A brief description of each land unit is given below, following the major land divisions. Reference is made to Appendix I, concerning soil types and extent by land unit and Appendix IV, which contains a table with a break down of each land unit into vegetation units, which in their turn have been broken down in soil types.

Alluvial system

The alluvial system measures 13,254 ha and covers 16.9% of the study area. It consists of the recent floodplain (land unit AS1) and the fossil floodplain (land units AS2-4) of the Boteti River.

Land unit AS1 has a flat to almost flat topography with slopes from 0-2%. The most dominant soils are Areni-Eutric Fluvisols (53%) and vegetation unit V2 (*Cynodon dactylon*, *Juncus* sp. and sedges) is most frequently found (coverage of 42%). Vegetation unit V1 (*Phragmites australis*) is only found here. The main present land uses are the collection of veld products from the river, grazing and watering of livestock in the river or in wells in the riverbed and molapo farming in times of flood.

Land unit AS2, the higher parts of the fossil floodplain, has an almost flat to gently undulating topography with slopes from 0.5-5%. The most common soil type is Eutri-Haplic Arenosol, occurring as a single unit (covering 65%) and in complex with Luvic Arenosols (covering 30%). Vegetation unit V9 (a dense savanna of *Albizia anthelmintica*, *Acacia erioloba*, *A. erubescens*, *Lonchocarpus nelsii*) covers 75% of land unit AS2. The dominant land uses are rainfed arable farming and communal grazing. The fields are located around the settlements. Grazing is done by animals kept close to the homes and on the way to the river for watering. In this land unit light to moderate wind erosion has been observed, which is related to the arable fields and the grazing pressure near the Boteti River. Light topsoil deterioration and nutrient depletion occurs on the farmers fields.

Land unit AS3, the depressions in the fossil floodplain, has an almost flat to gently undulating topography with slopes from 0.5-5%. Haplic and Petric Calcisols are the most common soils, and cover together 63%. The vegetation units V7 (*Terminalia prunioides, Acacia tortilis*) and V8 (*Acacia erubescens, A. leuderitzii, Boscia albitrunca*) dominate this land unit and cover 35% and 53%, respectively. The main present land use is communal grazing.

Land unit AS4, the pans in the fossil floodplain, have a flat centre and a slightly sloping rim. The only soil developed in the pans is a Luvi-Petric Calcisol. The vegetation unit V3 (grasses and forbs with clumps of open savanna typified by *Acacia mellifera* and *A. tortilis*) is found on the pans (covering 60%), while unit V7 (*Terminalia prunioides, Acacia tortilis*) frequently occurs on the pan fringes (covering 29%). Communal grazing is the main land use, while some light to moderate wind erosion happens, due to the low vegetative cover and the exposure of the pans.

Lacustrine system

The lacustrine system forms the most western tip of the Makgadikgadi Pan complex and has an extent of 4541 ha, which is 5.8% of the Chanoga AEA. It comprises a beach area (land unit LS1), depressions (land unit LS2) and pans (land unit LS3), belonging to a fossil lagoon.

Land unit LS1, the beach of the fossil lagoon, is slightly raised as compared to the units LS2 and LS3, and has an almost flat to gently undulating topography (slopes from 0.5-5%). The only soil found is a Eutri-Haplic Arenosol. The main vegetation unit is V4 (a savanna to dense savanna characterized by *Lonchocarpus nelsii, Terminalia sericea, Bauhimia petersiana, Commiphera pyracanthoides*), covering 77% of the land unit. The dominant land uses are communal grazing and the collection of veld products.

Land unit LS2, the depressions of the fossil lagoon, also has an almost flat to gently undulating topography with slopes from 0.5-5%. A total of 58% of the land unit is covered by Petric Calcisols. The vegetation units V8 (*Acacia erubescens, A. leuderitzii, Boscia albitrunca*) and V9 (*Albizia anthelmintica, Acacia erioloba, A. erubescens, Lonchocarpus nelsii*) are most frequently found, covering 38% and 43%, respectively. The dominant present land use is communal grazing.

Land unit LS3, the pans of the fossil lagoon, has a flat to almost flat topography, with slopes varying from 0-2%. The soils on these pans are all very shallow and classified as Eutric Leptosols. The single vegetation unit found is unit V6, a dense shrub savanna to savanna typified by *Acacia tortilis, Catophractes alexandri, Combretum imberbe*. The dominant present land use is communal grazing.

Sandveld

The sandveld is the largest of the three land divisions and has an extent of 60,500 ha, corresponding to 77.3% of the planning area. It consists of parabolic dune remnants (land unit SV1), interdunal depressions (land unit SV2) and minor pans (land unit SV3).

Land unit SV1, the parabolic dune remnants, is the largest land unit covering 47% of the area. It is characterized by a gently undulating topography with slopes from 2-5%. The most dominant soil is Eutri-Haplic Arenosol, which occurs as a single unit (covering 68%) and in a complex with Ferralic Arenosols (covering 32%). The main vegetation unit is V4 (a savanna to dense savanna characterized by *Lonchocarpus nelsii, Terminalia sericea, Bauhimia petersiana, Commiphera pyracanthoides*), covering 80% of the land unit. Rainfed arable farming is practiced on dune slopes in the southern portion of the sandveld, close to the settlements. The other prominent land uses are communal grazing and veld product collection. In the south, grazing takes place in the vicinity of the settlements, while in the centre and the north of the sandveld grazing occurs around cattlepost. Some light to moderate wind erosion and light topsoil deterioration and nutrient depletion is confined to the lands area.

Figure 7. Land Unit Map

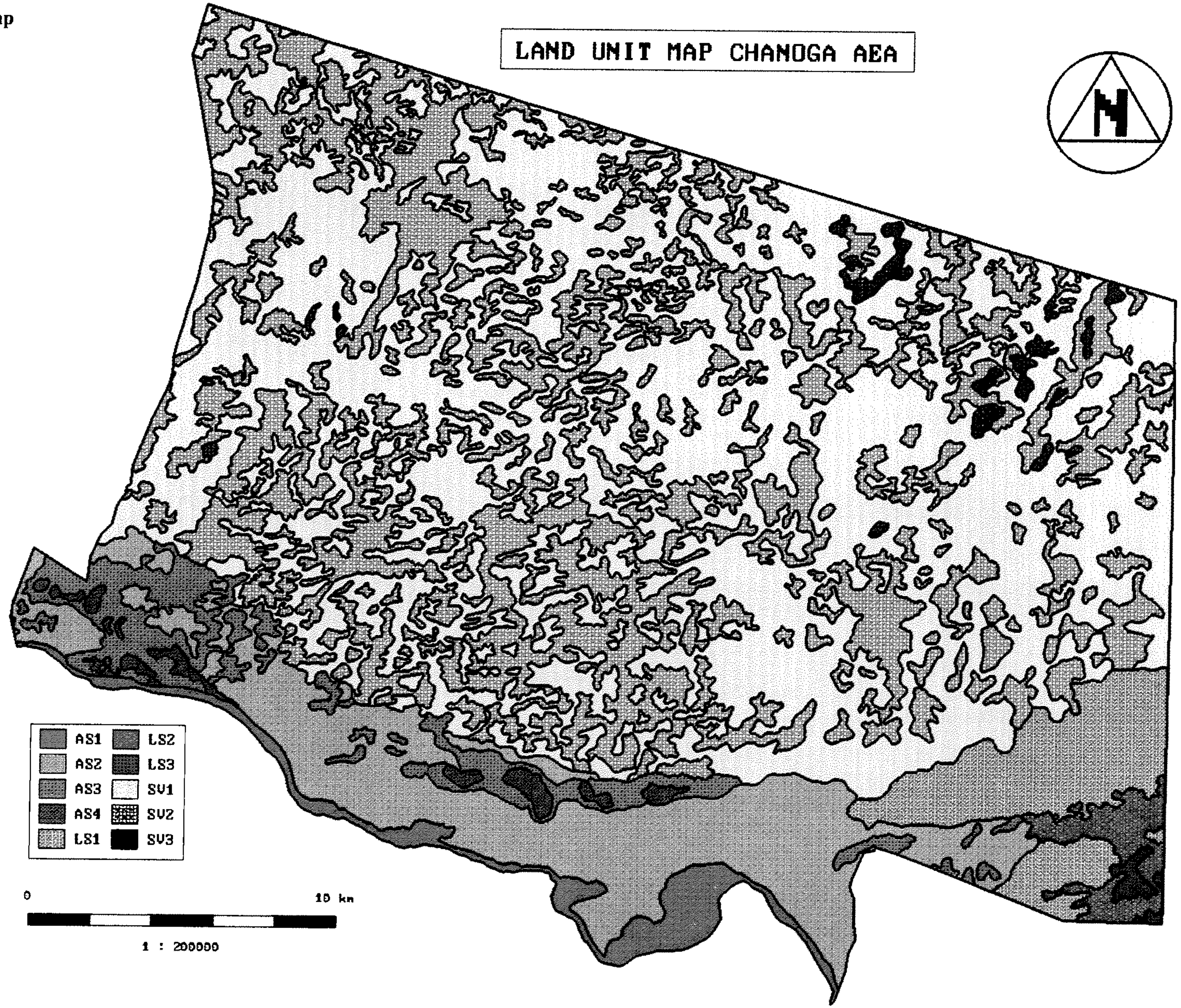


Table 9. Land unit characteristics

LAND UNITS CHANOGA AGRICULTURAL EXTENSION AREA — TOTAL AREA: 78.295 ha

SYNOPTIC STATION: MAUN — RAINFALL STATION: MAUN

LAND DIVISION	LAND UNIT	AREA (ha)	AREA (%)	LAND FORM	DOMINANT SLOPE (%)	SOIL TYPES FAO 1990	SOIL TYPES SLB 1990	WATER SITUATION	VEGETATION UNITS	DOMINANT PRESENT LAND USE
ALLUVIAL SYSTEM	AS1	1590	2.0	Recent Floodplain	0 – 2	CLplu, FLear, GLe, LPe, LVgcal, LVh	A9b, A24a, A31a, x 1), A7b, A14a	river, well points	V1, V2, V9, V11	veld products, grazing, molapo farming
	AS2	8266	10.6	Fossil Floodplain – higher parts	0.5 – 5	ARheu, ARl 2)	A40, A41	boreholes	V7, V8, V9	rainfed farming, grazing
	AS3	2829	3.6	– depressions	0.5 – 5	CLhar, CLpar, CLplu, LVhar	L11, A21a, A9b, A15a	pools of rainwater	V7, V8, V9, V11	grazing
	AS4	569	0.7	– pans	0 – 2	CLpluephypcal 3)	C5b	pools of rainwater	V3, V7, V8	grazing
subtotal:		13254	16.9							
LACUSTRINE SYSTEM	LS1	3457	4.4	Fossil Lagoon – beach	0.5 – 5	ARheu	L16, LS17d	nil	V4, V9	grazing, veld products
	LS2	916	1.2	– depressions	0.5 – 5	CLpar, CLplu, CLpluephypcal, LVhar	L12, L24b, C5b, L22a	pools of rainwater	V6, V8, V9	grazing
	LS3	168	0.2	– pans	0 – 2	LPe	C3	pools of rainwater	V6	grazing
subtotal:		4541	5.8							
SANDVELD	SV1	36694	46.9	Parabolic Dune Remnants	2 – 5	ARheu, ARo 2)	S17, S3	nil	V4, V8, V9, V10	rainfed farming, grazing, veld products
	SV2	23209	29.6	Interdunal Depressions	0.5 – 5	ARl, CLlsoar, CLpar, CLplu, LVhar 2)	S5b, L24c, L12b, L24b, L22a	boreholes, wells, pools	V4, V5, V6, V8, V9	rainfed farming, grazing, veld products
	SV3	597	0.8	Pans	0 – 2	CLl, CLlsoar	L24, L24c	pools of rainwater	V4, V6, V8	grazing
subtotal:		60500	77.3							

1) LPe, soil x in land unit AS1, not recognised in SLB 1990 – Revised Soil Legend of Botswana 1990.
2) Light to moderate wind erosion, light topsoil deterioration and nutrient depletion.
3) Light to moderate wind erosion.

N.B.: Only listed are those vegetation units, occupying more than 5 % of the repective land unit.
See Tables 3 and 6 for an explanation of the Soil Type and the Vegetation Unit codes.

Land unit SV2, the interdunal depressions, is the second largest land unit in the area, covering 30%. It has an almost flat to gently undulating topography, with slopes between 0.5-5%. The dominant soil is a Areni-Haplic Luvisol, found in 62% of the land unit. Vegetation unit V8 (*Acacia erubescens, A. leuderitzii, Boscia albitrunca*) is most frequently found in the depressions, covering 51%. Rainfed arable farming is done in several depressions in the southern portion of the sandveld, besides communal grazing and the collection of veld products. Grazing takes place close to the settlements and around cattlepost, similarly as described under land unit SV1. Light to moderate wind erosion and light topsoil deterioration and nutrient depletion is observed in the arable fields.

Land unit SV3, minor pans, has a flat to almost flat topography. The main soils found are Luvic Calcisols and the dominant vegetation unit is V4 (*Lonchocarpus nelsii, Terminalia sericea, Bauhimia petersiana, Commiphera pyracanthoides*), covering 39% of the land unit. Communal grazing is the main present land use.

The land evaluation exercises carried out in Chapter 6, used the land units as the basic unit for comparison.

4 SOCIO-ECONOMIC INFORMATION

4.1 Demography

The population of the Chanoga AEA is concentrated in Chanoga village and the settlements of Mawana, Tsibogolamatebele and Xhana. The average age of heads of households is 51 years (1994); no data is available on the age of individual family members.

4.1.1 *Population figures and household distribution*

The *de facto* population of the Chanoga Agricultural Extension Area amounted 1056 people during the Botswana Population and Housing Census of August 1991 (CSO, 1992). Table 10 shows the distribution of males and females over the different localities in the study area. The sex ratio (males per 100 females) in Chanoga AEA is 109.5, indicating a slight surplus of males. The latter figure differs from the ratio for the Ngamiland South Census District, of which Chanoga AEA forms a part, which amounts 93.3. The population density in the Chanoga AEA is 0.01 person per km^2, which is below the density of the entire Ngamiland Administrative District, which amounts 0.8 person per km^2 (CSO, 1992).

Table 10. ***De facto*** **population of Chanoga AEA, based on the Census of August 1991**

LOCALITY	TOTAL	MALE	FEMALE
Mawana	188	86	102
Chanoga	352	178	174
Tsibogolamatebele	201	114	87
Xhana	315	174	141
TOTALS:	1056	552	504

Table 11 shows the household distribution in the study area as compiled from the Seed Distribution Report 1993/94 of the Chanoga AD. The total number of households, that benefited from free seeds under the Drought Relief Programme is 233, which is virtually 100% of all households. Approximately 49% of the households is male headed and 51% is female headed. The average age of heads of the households is 51 years, varying between 19-90. The average age of male heads of households is five years higher than that of female heads of households: 53.5 years against 48.1 years, respectively.

Table 11. Household distribution, based on Chanoga Seed Distribution Report 1993/94

SUB EXTENSION AREA	HOUSEHOLD (hh) DATA						
	total hh	gender head M	gender head F	avg.age head hh	range	avg. age M head	avg. age F head
Chanoga	106	56	50	50.8	19-90	51.3	50.3
Mawana	63	28	35	52.2	22-86	54.1	50.4
Xhana	64	31	33	52.3	21-85	59.1	45.8
TOTALS:	233	115	118	51.0	19-90	53.5	48.1

4.1.2 Population growth rates

Assuming an average annual growth rate of 2.6% (based on the estimation given in DDP4 for the entire Ngamiland Administrative District), the total projected population for 1994 and 2004 should be 1201 and 1513 people, respectively (see Table 12).

Table 12. **Population projections Chanoga AEA**

YEAR	TOTAL	MALE	FEMALE
1994	1201	628	573
2004	1513	791	722

4.1.3 Age structure of household heads

Based on the Seed Distribution Report 1993/94, the frequency distribution of the age of household heads is depicted in Figure 8. The majority of household heads is 50 years or older (57%). Young heads of households are relatively scares, 10% of the total falls in the age group 20-29 years.

Figure 8. **Age distribution of heads of households, according to age class**

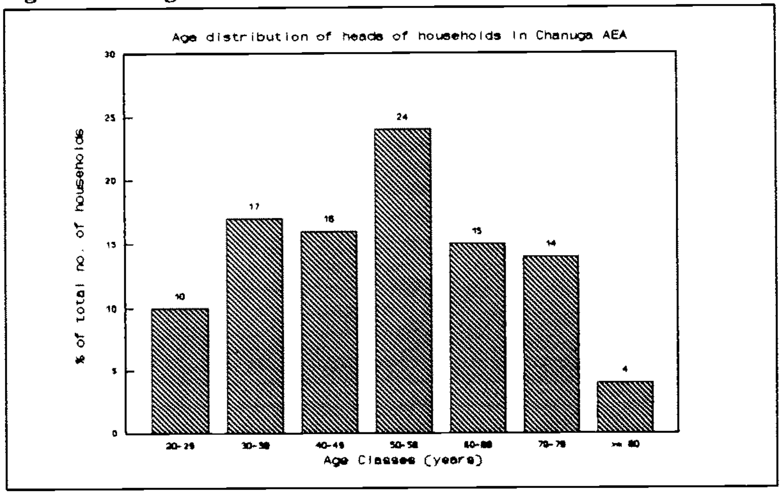
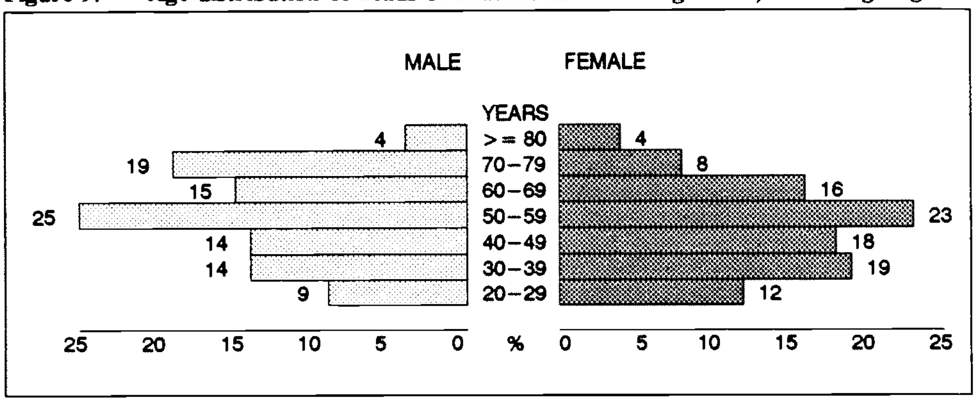


Figure 9 illustrates the distribution in age groups of household heads per gender. It appears, that 63% of the male household heads and only 51% of the female household heads is over 50 years of age, respectively. On the other hand, younger female heads of households are relatively more abundant than their male counterparts.

Figure 9. **Age distribution of heads of households in Chanoga AEA, according to gender**



From 46 farmers' interviews conducted in the Chanoga AEA during March 1995, the average household composition appeared to be 5.5 people per household. Multiplication of the total number of households of 233 with the average household composition gives a total population of 1272 people. The latter amount corresponds well with the population projection of 1201 people in 1994, as extrapolated from the 1991 Census data.

4.1.4 Migration

Despite the *de facto* population figures and household data as discussed above, the farm survey revealed, that a portion of the farmers resides in Maun during the winter months. Usually people move to the lands after the first rains in December, thus maintaining a kind of seasonal migration.

Approximately 55% of all households has one or more (temporarily) absent member. It often concerns children, who attend schools in Chanoga or Maun. These family members are normally available for farm labour during their school holidays. The Christmas holidays usually commence around December 10.

4.1.5 Ethnic composition of population

The Chanoga AEA is located in Batawana Tribal Territory. No exact figures are available, but most inhabitants of the planning area are believed to be Batawana, Bayei or Baherero.

4.2 Land tenure, local authorities and organizations

4.2.1 Land tenure in the planning area

The entire Chanoga AEA is located in communal (tribal) land. Traditionally land was allocated by the chief of the tribe with consent of the headman of the respective ward. After the Tribal Land Act (1968) came into effect, Land Boards were established.

The Chanoga AEA falls under the jurisdiction of the Tawana Land Board, which delegates part of its responsibilities to the Maun subordinate Land Board. Both Land Boards are responsible for the allocation of land under Customary Law and Common Law, depending on the land use applied for and the residence status of the applicant. Table 13 (after Bekker and Boom, 1995) summarizes the land allocation procedures in place in the Ngamiland District.

Table 13. Land allocation procedures

STATUS	LAND USE	LAND RIGHT	ALLOCATING LAND BOARD
Citizen	- residential use - arable farming	Customary Law	subordinate Land Board
	- borehole/well	Customary Law	Tawana Land Board
	- all other uses (commercial etc.)	Common Law	Tawana Land Board
Non-citizen	- residential and all other (commercial etc.) uses	Common Law	Tawana Land Board

Once land has been allocated, a lease agreement with a specified term is prepared by the Land Board. The lease holder effectively has exclusive rights over the use of the land, for the period stipulated in the lease, as long as he/she continues to occupy and utilize the land/plot.

All interviewed farmers replied, that they had registered the land they use for rainfed arable farming with the Land Board. Molapo fields are not allocated by the Land Board, as they are considered temporary. However, individuals do make claims over pieces of land that can even be passed on to their offspring.

Grazing land is not allocated and livestock can range freely on communal land. Farmers are free to establish a cattlepost in the communal grazing areas. For boreholes and wells, however, a land right has to be obtained from the Land Board. Once granted a land right for a borehole or well, the owner has *de facto* rights to the water and the surrounding grazing area.

4.2.2 Local authorities and organizations in the planning area

In the village of Chanoga resides a Chief's Representative who has the authority over the whole of the extension area. In Xhana there is a recognized, but unofficial head of arbitration.

The Chanoga AEA is located in the constituency Makalamabedi North and is represented by a BNF Councillor (1996) in the North West District Council.

The main Village Development Committee (VDC) is based in Chanoga, with sub-VDC's in Mawana and Xhana. Farmers Committees exist in Chanoga, Mawana and Xhana.

4.3 Legislation and government assistance programmes

4.3.1 Development Plans and National Policies

The observations and recommendations done in this plan fit in the legal framework, created by the National Development Plan (NDP) 7, the Ngamiland District Development Plan (DDP) 4 and several National Policies. The most relevant Policies for agricultural development are the New Agricultural Policy, the National Conservation Strategy and the Wildlife Conservation Policy.

NDP 7 (MFDP, 1991) formulates the following Policy Objectives for the agricultural sector:

- to improve food security at both household and national levels
- to diversify the agricultural production base for more income generating opportunities
- to increase agricultural output and productivity
- to increase employment opportunities for the rapidly growing labour force
- to provide a more secure and productive environment for those engaged in agriculture
- to conserve scarce agricultural and land resources for future generations.

In the Ngamiland DDP 4 (NWDC, 1989) the following priority listing regarding development projects has been given:

- to develop facilities capable of supporting development; i.e. improvement of communication systems (roads, telephone etc.)
- to increase income opportunities through increased production and employment
- development of irrigated agriculture, poultry, dairy and fisheries.

The National Policy on Agricultural Development (GOB, 1991), the New Agricultural Policy, has the objectives as described above under DDP 7. In addition, the government gives priority to increasing sustainability, resource efficiency and environmentally compatible production systems and programmes.

The National Conservation Strategy (GOB, 1990) focusses on natural resources conservation. The main environmental issues dealt with by the Strategy are the pressure on water resources, rangeland degradation, depletion of wood resources, overuse of veld products, pollution, urban expansion, the conservation of wildlife and cultural heritage. The Strategy intends to achieve its goals through encouragement of economic diversification, economic incentives and disincentives, legislation reforms and provisions, planning and administrative measures, public awareness, improved education and training.

The Wildlife Conservation Policy (GOB, 1986) aims at promoting the utilization of the wildlife resource in a sustainable way. The policy recognizes the need to obtain a higher financial return from land allocated to wildlife utilization, while at the same time ensuring the continuity of the resource. Special attention is paid to community wildlife utilization. Local communities living in specific areas can decide in which way the wildlife resource should be used. The community receives the benefits (meat, wildlife products, hunting revenue). This approach is hoped to create a different attitude towards wildlife and living in wildlife areas, and in the long term achieve the conservation of the resource.

4.3.2 Government assistance programmes

The people in rural areas, like the Chanoga AEA, can benefit from the following Government assistance programmes:

The AE-10 programme is targeted to farmers, who are united in a group. Projects that are financially supported, are undertaken by VDC's, Farmers Committees or other management groups, that intend to create new agricultural facilities or contribute to an increase in agricultural production (e.g. group fencing, electrical fencing, gardens, etc).

The Arable Lands Development Programme (ALDEP) was designed to assist arable farmers with less than 40 head of cattle or a yearly cash income < P 7500. During phase I of the ALDEP programme farmers could obtain draught power, implements, fencing material, scotch carts and water catchment tanks. Depending on the amount of cattle owned, farmers paid a down payment towards the packages of at least 15% of the total price. Phase I came to an end in June 1993. Phase II of the ALDEP programme was launched mid 1996. Phase II is concentrating on the transfer of technologies to improve crop production, but the same implement packages as under Phase I are still available.

The Drought Relief Programme has three components: a) labour based projects, b) assistance to arable farmers, and c) assistance to livestock owners. The first is aimed at creating employment for rural people. Small building projects (VDC houses), road works, firebreak construction and maintenance are carried out. The District Council coordinates these projects and the selection of participants is done by the VDC's. Criteria for selection are the degree of affectation by drought of individuals and households, in order to equally distribute the relief amongst all members of a community. The second component of the Drought Relief Programme consists of a package of subsidies for ploughing, rowplanting and free seeds. The last component includes assistance to drill and equip boreholes and a livestock feed subsidy.

The Financial Assistance Policy (FAP) aims at assistance in the development of industrial and agricultural enterprises, in order to create more employment and to diversify the economy. FAP loans and grants mostly applied for in the agricultural sector, are used for the development of irrigation/horticultural and poultry/smallstock projects.

The programme Services to Livestock Owners in Communal Areas (SLOCA), addresses the needs of livestock owners on the communal lands. Funds under this programme are provided to groups of farmers, and encompass grants for stock enclosures, equipment, dipping, water supplies, fencing, firebreaks and land rehabilitation.

The Fencing Component of the New Agricultural Policy advocates fencing of communal land in order to improve livestock production and range conditions. In the framework of this Policy assistance is provided to individuals, syndicates or community farms in the form of subsidies for water development and fencing.

From the farm survey held in the Chanoga AEA, it appears that all interviewed farmers have knowledge of the ARAP, ALDEP and Drought Relief assistance schemes. All farmers have made use of the drought relief packages, while only 36% of the farmers has obtained implements through ARAP and/or ALDEP. The reasons for not using these schemes are not clear. FAP and AE-10 are known by 83% and 75%, respectively. No figures are available on the use of these two schemes.

4.4 Economy

4.4.1 Economic activities and income

The main economic activities and sources of income of the inhabitants of the Chanoga AEA can be divided into two groups:

Farming activities

- Arable farming; sales of produce
- Livestock production; sales of cattle and smallstock

Normally all household members are involved in farm activities. In most farming families children form a critical part of the labour force. Their contribution ranges from ploughing, bird scaring, water and fuelwood collection to milking and watering of livestock. Labour required for proper crop and animal husbandry is normally insufficient. This is partially caused by the absence of family members, that have (temporarily) gone for schooling or employment to Chanoga or Maun. At times casual labour is hired for crop production related activities as ploughing and weeding. At cattleposts some labour is permanently employed to look after the animals.

Off-farm activities

- Wage labour and remittances
- Drought Relief a) labour based projects
  b) arable subsidies
- Collection and sales of veld product and derivatives

During the socio-economic survey farmers appeared to be very reluctant to provide information regarding their income. The majority answered, that the sales of grain was their most important source of cash income, followed by the sales of livestock and employment in labour based Drought Relief projects. However, data on obtained prices were not easily volunteered. Not one interviewed farmer mentioned drought relief payments, nor remittances as a source of income. Hence, no reliable income breakdown for a "typical" household situation can be given.

Approximately 70% of all households saw their cash income decreasing over the past 5 years. Due to drought crop production was poor, livestock died and few veld products, nor fish could be collected from the river. Around 30% mentioned an increasing in income over the past 5 years, mainly due to drought relief ploughing subsidies.

4.4.2 Farmer Groups

An important objective of the socio-economic survey was to identify groups of farmers with similar resources in terms of land, labour, capital and draught power. Farmers stratified accordingly, show similar management constraints. Suggestions for improvement of their production systems, in the form of extension recommendations, can thus be targeted to specific groups of individuals.

It should be noted, that the farmer grouping is partially based on cattle ownership. As all cattle in the Ngamiland District (apart from the Hainaveld Ranches) was destroyed by end 1996 due to the outbreak of the cattle lung disease (contagious bovine pleuropneumonia), the proposed grouping only has a historic value.

The availability of resources is classified as shown in Table 14. The parameter class boundaries have been chosen to reflect a realistic division in the spectrum of each resource. The area cultivated can be much smaller than the actual size of the field owned. This was considered more appropriate to use for classification purposes, as farmers' efforts are concentrated on this tract of land. The available family labour units give an indication of the efficiency of the farming system. The potential is calculated from the household composition data by assigning 1.0 unit to an adult (≥ 18 years) male family member, 0.6 unit to an adult female family member and 0.2 unit to a child family member (≥ 10 years). The division according to capital is based on an approximation of numbers of livestock and types of implements owned. The class "poor" is defined by ≤ 10 cattle equivalents, "well-off" by 11-30 cattle equivalents and "rich" by ≥ 31 cattle equivalents. One cattle equivalent is composed of 1 cow/ox, 2 donkeys or 4 goats, respectively. The availability of draught power is assessed on the basis of access to this resource.

Table 14. Boundaries of parameter classes for farmer grouping

Area cultivated (ha)	A1: 0 - 2	A2: >2 - 5	A3: > 5
Labour units	L1: 0 - 2	L2: >2 - 3	L3: > 3
Capital (cattle equivalent)	P: poor (≤ 10)	W: well-off (11 - 30)	R: rich (≥ 31)
Draught power	D+: access to	D-: no access to	

Based on the above criteria, the farming households could be divided in three classes based on their capital resources. Groups could be identified according to area cultivated (groups P and R) and labour availability (group W). Subgroups were distinguished with regard to dedication to arable farming, reflected in timeliness of management operations.

Table 15. Farmer groups (all households)

CLASS	GROUP	SUBGROUP	GROUP	SUBGROUP
P (45 %)	P1 (11 %), A1	P1a	P2 (34 %), A2/A3	P2a
		P1b		P2b
W (28 %)	W1 (17 %), L1/L2	W1a	W2 (11 %), L3	W2a
		W1b		W2b
R (27 %)	R1 (25 %), A2/A3	R1a	R2 (2 %), A1	
		R1b		

The parameters P,W,R,A and L have been quantified in Table 14.

FARMER GROUP P1

These households are typified by a poor capital status (P, ≤ 10 cattle equivalents) and plough a piece of land up to 2 ha (A1). They often have access to draught power through borrowing or sharing with relatives. This group usually broadcasts their seeds not before the third dekad of December, due to a lack of labour earlier (school going children). The household subsistence requirements of grain are hardly ever met. They normally plough themselves, in order to cash the drought relief subsidies for ploughing. The collection of veld products for home consumption and sales is essential.

Members of subgroup P1a do not hold a Land Board certificate for their field, and are therefore not eligible to ALDEP support. They do not possess a plough. Group P1b households on the contrary, have their land registered at Land Board and can obtain ALDEP support and normally own a plough.

FARMER GROUP P2

This group of farmers is characterized by a poor capital status (P, ≤ 10 cattle equivalents) and plough a piece of land ≥ 2 ha (A2/A3). Although poor, usually a minimum of four donkeys is owned for draught power. Seeds are normally broadcasted and subsistence grain requirements are not fulfilled. Ploughing is done by household members, in order to cash the drought relief subsidies. The collection of veld products for home consumption and sales is important.

Farmers belonging to subgroup P2a seem to be less dedicated to arable farming and tend to plant after the second dekad of December. Subgroup P2b consists of more dedicated farmers, who manage to start planting after the first planting rains (20mm), between the third dekad of November and the second dekad of December.

FARMER GROUP W1

This group is reasonably well-off (capital status W, possessing 11-30 cattle equivalents), plough different hectarages of land, but have a somewhat limited household labour force (L1/L2). These households have substantial resources for arable farming and can afford to hire labour and/or draught power (animals or tractor) for ploughing. They usually possess a plough. Nevertheless subsistence grain requirements are hardly ever reached. The collection of veld products for home consumption and sales is important.

Farmers belonging to subgroup W1a seem to be less dedicated to arable farming and tend to plant after the second dekad of December. Subgroup W1b consists of more dedicated farmers, who manage to start planting after the first planting rains (20mm), between the third dekad of November and the second dekad of December.

FARMER GROUP W2

This group is also reasonably well-off (capital status W, possessing 11-30 cattle equivalents), plough different hectarages of land, and have sufficient family labour (L3) and draught power. They normally possess a plough, or are able to hire a tractor. The grain subsistence requirements of these households are generally met. This group has the potential to adopt improved farming practices and to produce a surplus for sale.

The less dedicated farmers belong to subgroup W2a and broadcast their seeds after the second dekad of december. The more dedicated farmers, subgroup W2b, possess a harrow and/or a row planter. They start planting after the first planting rains (20mm), between the third dekad of November and the second dekad of December.

FARMER GROUP R1

These households are relatively rich (capital status R, possessing $\geq$ 31 cattle equivalents) and cultivate > 2 ha (A2/A3). Members of this group have no major resource constraints and can afford to hire labour and/or a tractor for ploughing. They normally possess a plough and subsistence grain requirements are met. These farmers have the greatest potential to adopt improved management operations and to farm on a commercial scale.

There still exists a portion of group R1 farmers, that broadcast their seeds after the second dekad of December. They are probably less dedicated to arable production and are grouped in subgroup R1a. The dedicated farmers gathered in subgroup R1b, usually possess a harrow, rowplanter and cultivator. They start planting after the first planting rains (20mm), between the third dekad of November and the second dekad of December.

FARMER GROUP R2

This group of relatively rich farmers only ploughs an area < 2 ha (A1). Arable production does not seem to have a high priority; they usually do not meet their grain subsistence requirements. They are livestock rearers, owning $\geq$ 31 cattle equivalent, which are normally kept at a cattlepost. No subgroups have been distinguished here.

The majority of all households, 45%, belongs to the class of poor households. The well-off and rich classes cover 28% and 27% of all households, respectively.

Group P1 contains 11% of all the farming families; 2% is male headed and 9% is female headed. The largest portion of the population, 34%, belongs to group P2; 25% are male headed households and 9% female headed. Group W1 is formed by 17% of all households; 11% is male headed and 6% female headed. Group W2 consists of 11% of all households; 9% is male headed and 2% is female headed. To group R1 belong 25% of all farming families; they are all male headed. Group R2 only consists of 2% of the community and only contains male headed households.

A breakdown of the same farmer groups according to gender of the head of the household is presented Table 16.

Table 16. Farmer groups per gender of household heads

Female headed	P1 33 %	W1 25 %	R1 -
	P2 33 %	W2 9 %	R2 -
Male headed	P1 3 %	W1 14 %	R1 34 %
	P2 34 %	W2 12 %	R2 3 %

From the Tables 15 and 16 the following conclusions can be drawn:

* The majority of all households is poor (class P 45%)
  - Of the female headed households most are poor (class P 66%, equally distributed over the groups P1 and P2)
  - Male headed households are relatively evenly distributed over all capital classes; 37% is poor (group P1 3% and group P2 34%)
* A total of 28% of all households is well-off (class W)
  - Of the female headed households 34% is well-off (25% in group W1 and 9% in group W2)
  - The group of well-off male headed households encompasses 26% of all male headed farming families (groups W1 14% and group W2 12%)
* The rich class contains 27% of all households (class R)
  - No female headed households did qualify for this class
  - All rich farming families are male headed and of the total of male headed households 37% is rich (group R1 34% and group R2 3%).

From the data of the socio-economic survey it appears, that the ratio male headed - female headed households is 74 - 26%. This does not correspond with ratio 49 - 51%, as derived from the Seed Distribution Report as mentioned in Section 4.1.1. Reasons for this discrepancy could be sought in the presence or absence of male heads of households at the time of registration (*de facto* and *de jure*) or in the fact, that individual adult household members are eligible for drought relief subsidies including free seed.

4.4.3 Management-, production- and farming systems

Definitions

A management system is defined by a set of management operations and inputs that are applied in a specific way to produce a given product.

A production system is defined as the specific combination of a product and a management system.

A farming system is defined as the combination of the decision making unit (here the farm household), its land and its production systems.

Agricultural calendar

Crop production, livestock rearing and veld product collection are the main agricultural activities in the extension area.

In most households, the months of November to June are reserved for arable farming. From July to October different activities are carried out; 55% of heads of household are mainly involved in livestock rearing and upgrading of the fields (bush clearing and mending of fences), 27% has occupations in the village, 9% works in a labour based drought relief project and 9% conducts a winter ploughing operation.

In general, 78% of farmers tend to spend less time on arable farming activities over the past years. Reasons given are drought, the use of a tractor for ploughing and more time needed for watering of livestock. 11% devotes the same amount of time to crop and livestock production as it did five years ago. The last 11% spends more time in crop production, due to an increase in the area cultivated.

4.4.3.1 Rainfed arable farming

In the following section, the most common production systems found in the planning zone are described. The information provided is based on 1990/91 ARAP Records, the Drought Relief and the Seed Distribution Reports for 1993/94 from the Chanoga AD, on the conducted socio-economic survey and on additional observations.

Setting

In an average rainfall season, all households in the planning area are involved in rainfed arable farming. The main crops are maize and sorghum, which are normally grown in a broadcast crop mixture with cowpeas and watermelon. Yields are typical for traditional low input agriculture, ranging from 1 to 3 (70 kg) bags per hectare. Normally the production is used for subsistence of the farming household.

During a survey conducted for drought relief compensations under the ARAP scheme over the season 1990/91, the entire extent of all fields (whether ploughed or not) was measured. Usually the total field owned by farmers is larger than the actual area planted. As that particular season coincided with good rains, the measured total is considered the baseline area of arable lands in the Chanoga AEA, being 1543 ha.

During the ploughing season 1993/94, which was marked by good rains, 872 ha was ploughed (56% of the baseline area). This meant an average of 3.1 ha per household. The male headed households managed to plough a slightly bigger field as compared to the female headed households, 3.3 ha against 2.9 ha, respectively. The area cultivated ranged from 0.2 to 15 ha. Of the total of 872 ha, 96% was broadcasted and only 4%, 34 ha, was row planted. On average 2.7 ha was row planted per row planting household; 3.9 ha by male headed households and 1.6 ha by female headed households.

In total 674 pockets of 10 kg of free seed were distributed during the 1993/94 cropping season as part of the Drought Relief assistance. Farmers were eligible for seeds upto 4 pockets to their choice, depending on the hectarage ploughed the previous year (1 pocket per hectare). A total of 568 pockets of maize seed were obtained by 225 beneficiaries (2.5 bag per farmer), 84 pockets of sorghum seed were supplied to 64 beneficiaries (1.3 bags per farmer) and 22 pockets of millet seed were provided to 18 beneficiaries (1.2 bags per farmer). No cowpea seed was available. The seeds were on average equally distributed over male and female headed households.

Management practices and inputs

Crops

Maize var. *Kalahari Early Pearl* is the most popular grain crop grown. It is preferred above sorghum by many because of the taste and because it does not involve the labour intensive activity of bird scaring. Sorghum var. *Segaolane* and the local variety "gooseneck" are common. Sorghum and millet (occasionally grown), are more drought resistant than maize, but have as disadvantage, that the heads are prone to bird damage. Cowpeas are widespread, but normally grown in small hectarages. They are reputed by farmers to do well, even under low rainfall conditions. Groundnuts are not often grown in the extension area. Sweet reed and melons are cultivated as minor crops, but are normally the only cash crops.

Labour

Generally rainfed arable farming is carried out with farm labour. A gender related distribution of tasks is normally observed. Typically male jobs are mending fences, bush clearing and ploughing/planting, while women are mainly involved in weeding, bird scaring and harvesting. Children assist in all management operations, but mostly in weeding and bird scaring.

From all households, however, 34% hired a contractor for ploughing (the same figure applied to both male and female headed households) during the 1993/94 cropping season. At the start of the ploughing season a temporary labour shortage can occur, due to school going of children. This problem is solved during school holidays. Later in the season a shortage is observed, at times, for weeding and bird scaring activities.

Soil nutrient status

Traditional crop production leads to nutrient depletion of the soil substrate. Crop residue is not ploughed back in the soil, as livestock and smallstock is allowed to graze this off, after the harvest. Some manure, however, is returned to the soil in this process. Kraal manure, nor chemical fertilizer are used in a structural manner.

Ploughing

All surveyed households had access to draught power through ownership, borrowing, sharing or hiring. Most farmers use one or two spans of 2 donkeys for ploughing. As the majority of soils has a sandy top, donkey power is sufficient. The average number of donkeys owned per household is 5; on average 6 donkeys are possessed by male headed and 3 by female headed households, respectively. Approximately 12% of all households does not own donkeys; 3% of all male headed and 38% of the female headed households is lacking this resource (see Section 4.4.3.4).

Nobody reported to use oxen. Although no figures available, the number of tractors owned by residents of the planning area is estimated at a maximum of 3. However, some contractors from outside the Chanoga AEA are know to rent out their tractor ploughing services to farmers in the study area.

Ploughing is usually done 1 or 2 days after a rainfall event of a minimum of 20-30mm. The delay is explained as time required for the rain water to infiltrate and to fully wet the soil profile.

Planting

Planting is normally done in the form of broadcasting of a mixture of seeds of the above mentioned crops. The time of planting depends on the combination of the availability of labour and sufficient rainfall. Broadcasting is carried out on the same day as ploughing and traditionally a start is made after Christmas, during the third dekad of December.

Where a tractor was hired, broadcasting was done prior to the ploughing operation. Rowplanting (of a monocrop) was only done by 4% of all farming households during the 1993/94 cropping season.

Weeding

Usually one weeding operation is carried out, approximately 4-6 weeks after planting. Weeding is done with a hand hoe, as soon as weeds have reached knee height.

Pest and disease control

For the crops sorghum and millet bird scaring is indispensable. This is a time consuming operation, that has to be carried out from dawn to dusk during the grain filling and early ripening stage of the crops. Often domestic activities and large fields hamper an effective operation. Migrating Quelea birds are the main culprits.

Aphids do occur regularly. When they happen during the late vegetative crop stage, a rain shower suffices to wash them of the affected plant, without damaging the crop. Army worm occurs occasionally. In case of an outbreak the Plant Protection Division is contacted and conducts a spraying operation with Alphametrion. Stalk borers, corn crickets, African bollworm and termite infestations have been observed causing considerable damage to plants. Individual farmers do not use any pesticide to control plagues.

Crop damage due to livestock, smallstock or small antelopes (steenbok, duiker) is regularly reported. Poor condition of fencing is often debet to this type of "pest".

Harvesting

Sweet reed and green mealies are usually harvested early and consumed by the family members and occasionally sold in the village.

Many sorghum growers are not interested in small immature heads or in heads with only partially filled grains (so called "mothalane"). After approximately two weeks of harvesting mature heads, they stop and leave the immature heads behind.

From cowpeas the fresh leaves are picked and eaten as vegetable. Beans and maize cobs are harvested, when dry. Ripe melons are harvested and eaten or sold at wish.

Storage and post harvest losses

Storage of grains takes place in drums (45%), in a granary (36%) and in sacks (19%). Most post harvest losses are attributed to weevils and rats. Half of the households mixes the grains with ash from cow dung to protect the produce against attacks from weevils. Figures on the percentage of post harvest losses are not available.

Production systems

Two major crop production systems have been observed in the Chanoga AEA:

- mixed cropping in rotational management system
- mixed cropping by a single farming household

Both production systems are based on the inputs and management operations as described in the previous section. The main differences are the timing of operations and the management of human resources and implements.

Rotational management system

This production system is characterized by a management system, which is based on sharing the available labour, draught power and implements among several adult family members. These practices occur in approximately 75% of all farming households. The individual fields form part of one large fenced arable area, which in most cases belongs to the head of the family.

From the start of the cropping season, all management operations are carried out on a portion of each family member's field on a rotational basis. After finalizing work on a part of the last member's field, the work force starts again at the first member's field; this rotation is repeated until planting of the entire field of each relative has been completed.

This system is practised to spread the risk of crop failure by planting at different intervals through the season and also ensures all family members of enough labour and access to the right implements to carry out the necessary activities.

Single farming household

These production systems are typified by a management system practised by a single farming household (25% of all households). For this management system the individual farmer has the necessary inputs, implements and labour at his/her disposal to carry out all the management operations independently.

Although not provable with survey data, it is assumed that the rotational system is most found amongst the more resource poor farmer groups P1, P2 and W1, while the single farming household occurs under the more wealthy farmer groups W2 and R1.

The more resources a farming household has, the greater the chance for flexibility in the production system and the higher the likelihood of adoptation of extension messages (groups W2 and R1).

4.4.3.2 Molapo farming

Molapo (flood recession) farming is practiced at many places in the floodplain along the entire Boteti River. Fields are usually small, approximately 1 ha. When the Boteti River actually flows, the flood from the Okavango Delta comes through in July/August. In good years, the flood water inundates the entire floodplain from bank to bank. Farmers wait for the water level to drop and for the river to confine itself to the central channel. Only then (August/September) can they start ploughing and planting their fields, that stretch across the floodplain to the channel. The most commonly grown crop under molapo farming is maize. The available soil moisture gives plants a head start as compared to rainfed crops. By benefitting from the early season rains (October/November) crops should be ripening off in December/January.

The maize is grown for the sales of green mealies and for the dried grains. The plant density used is around 30,000 plants/ha. Usually a weeding operation takes place 30 days after planting.

In years that molapo farming can be practiced, farmers concentrate on their molapo fields first, before ploughing/planting a portion of their dryland field. Some farmers cultivate a field in the floodplain (molapo field) under rainfed conditions every year.

4.4.3.3 Horticulture / irrigated farming

Due to a lack of surface water, only one horticultural project is operational in the planning area. This project concerns a citrus orchard, consisting of approximately 150 orange and lemon trees.

The trees are watered from a borehole and produce is sold in Maun. No yield or financial returns are known.

One horticultural project was forced to move to a plot along the Boro River, northeast of Maun, while a few scheduled projects never came of the ground.

4.4.3.4 Livestock production

All information given in this section is based on historic data. It should be realized, that the outbreak of the cattle lung disease has changed the picture completely. All cattle on communal land in the entire Ngamiland District (approximately 300,000 beasts) has been destroyed by end 1996.

Livestock distribution

It results from the farm survey, that the majority of all households in the Chanoga AEA is involved in livestock production. In total 82% of all households is owning cattle and/or goats. Cattle and/or goats are kept for subsistence and cash needs. Donkeys are owned by 88% of all households and are used as draught power and as mode of transport. Livestock numbers, though, are unevenly distributed amongst the households (see Tables 17 and 18).

Table 17. Average numbers of livestock per household

LIVESTOCK SPECIES	ALL HOUSEHOLDS	MALE HEADED HOUSEHOLDS	FEMALE HEADED HOUSEHOLDS
Cattle	15	19	3
Goats	22	28	7
Donkeys	5	6	3

From the above Table 17 the following conclusions can be drawn:

* Average cattle herds and flocks of goats are relatively small
* Male headed households own on average more livestock in all three categories than female headed households.

Table 18. Breakdown of livestock ownership in classes per household (percentages)

LIVESTOCK SPECIES	CLASS	ALL HOUSEHOLDS	MALE HEADED HOUSEHOLDS	FEMALE HEADED HOUSEHOLDS
CATTLE	none	37	28	61
	1 - 10	35	36	31
	11 - 30	18	22	8
	≥ 31	10	14	0
GOATS	none	23	19	31
	1 - 40	61	59	69
	≥ 41	16	22	0
DONKEYS	none	12	3	38
	1 - 6	59	67	39
	7 - 12	25	25	23
	≥ 13	4	5	0

From the above Table 18 and interview data the following conclusions can be drawn:

* 3% of all households does not own any livestock. Male headed households always own some kind of livestock, while 23% of the female headed household is without
* 18% of all households do not own cattle and/or goats; 14% of the male headed and 31% of the female headed households fall in this group
* 37% of all households do not own cattle. This reflects the national picture, where 38% of all farming households is without cattle (NDP 7, MFDP 1991). Double the amount of female headed households, however, does not own cattle as compared to male headed households: 61% against 28%
* A similar percentage of male and female headed households owns between 1-10 head of cattle (36% versus 31%). Male headed households are better represented in the higher cattle classes; 36% owns more than 11 heads, while only 8% of the female headed households qualifies for this group. Female households are not even present in the class of large cattle owners, while 14% of the male headed households owned more than 31 heads
* 23% of all households does not own any goats (19% of all male and 31% of all female headed households). All female goat owners (69%) fall in the group 1-40 animals, while 59% of the male headed households owns 1-40 goats and 22% 41 or more
* 12% of all households does not own any donkey; 3% of the male and 38% of the female headed households respectively. 67% of the male against 39% of the female households owns between 1-6 donkeys. Only a small group of male headed households (5%) and no female households claimed to possess 13 or more donkeys.

In the planning area, 4 communal and 4 private cattle crushes have been found. At these crushes cattle is vaccinated by the Veterinary Department. Table 19 shows the number of cattle vaccinated against Foot & Mouth Disease (FMD) during the campaigns of March 1992 - March 1995.

Table 19. Cattle figures Foot & Mouth Disease Campaigns[1]

CRUSH	March 1992	Sept 1992	March 1993	July 1993	March 1994	Sept 1994	March 1995
Chanoga [c]	430	707	887	557	1223	126	348
Kanana [p]	110	112	65	56	38	86	84
Kasanga [p]		30	104	104			80
Mawana [c]	554	343	548	346	706	38	157
Phefodiafoka [p]	312	246	344	288	269	244	233
Tshipidi [p]	188	132	164	75	76	136	165
Xhadamo [c]	576	636	774	457	941	1585	423
Xhana [c]		370	481	511	655	760	410
TOTALS:	2170	2576	3367	2394	3908	2975	1900

[1] source: SVO Maun   c - communal crush   p - private crush

From the above Table 19 the following conclusions can be drawn:

* Although the figures of three campaigns are not complete, one trend is clear: the cattle numbers are highest in March and lower in July/September. This phenomenon can probably be attributed to the fact that calving mainly takes place during the rainy season (November-March), when the range and water conditions are at best. Towards the winter pressure on grazing areas and for water increases. This is accompanied by sales of cattle, a higher mortality and migration to other extension areas.
* From March 1992 until September 1994, a steady increase in cattle numbers is noted. A sudden drop occurs in March 1995. The rainfall season 1994/95 was extremely bad (approximately 200mm) and grass did not get the chance to germinate. The drought conditions

(poor grazing and water situation) increased mortalities and made farmers to decide to migrate to "greener pastures".

The Veterinary Department conducts a Stock Census at the beginning of each year. The figures of the crushes in the planning zone for 1995 are presented in Table 20.

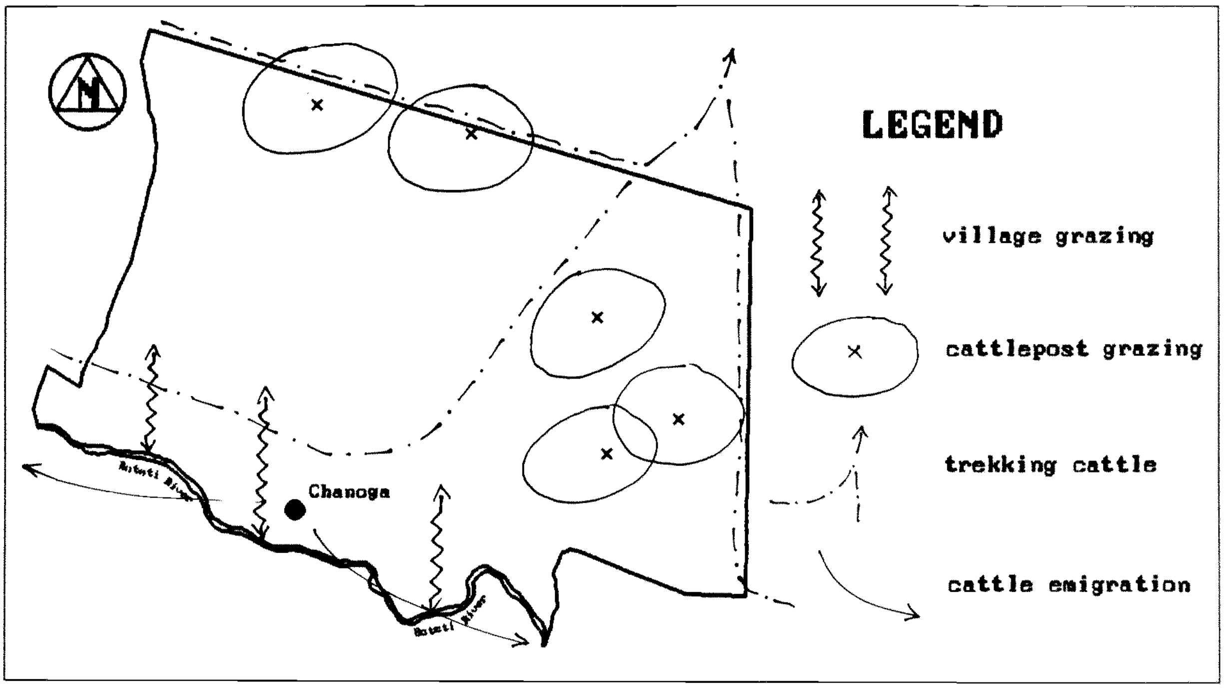
Table 20. Stock Census data 1995

CRUSH	Bulls	Cows	Steers	Calves	Total Cattle	Horses	Donkeys	Goats	Sheep
Chanoga	1	60	21	27	109	6	52	216	
Kanana	1	31	5	41	78	1	5	14	
Kasanga	1	46	12	19	78		10	34	
Mawana		150	11	62	223	13	51	278	
Phefodiafoka	1	33	13	10	57				
Tshipidi	3	107	13	47	170	2			
Xhadamo	3	250	67	112	432	11	74	427	25
Xhana	8	418	158	142	726	18	151	821	18
TOTALS:	18	1095	300	460	1873	51	343	1790	43

The total number of 1873 head of cattle as counted in the Stock Census corresponds very well with the 1900 head vaccinated during the March 1995 FMD campaign. Extrapolating from the farm survey, however, the total cattle herd in the AEA consists of 3495 animals, the total goat population is 4905 and the total number of donkeys amounts 1165. The discrepancy with recorded figures could be explained by the submission of underestimates by farmers.

The animals mentioned in Table 20 are unevenly distributed over the planning zone and cause unequal pressure on the grazing resource in different sections of the AEA. An estimated 70% is kept around the settlements, whereas 30% grazes from cattleposts. Figure 10 shows a sketch map with the major concentrations and movement patterns of livestock.

Figure 10. Livestock concentrations and movement patterns



The resources are not only used by the "resident" herds and flocks, but also by cattle, that is regularly trekked through the Chanoga AEA on its way to the Shorobe Quarantine Camp. The trekked animals including accompanying horses and donkeys are estimated at 250 LSUs present in the study area on a daily basis. The most commonly used trek routes are along the main Nata-Maun road, along the western fence of the Makalamabedi Artificial Insemination Camp, along the pipeline from the Boteti River to the Shorobe Quarantine Camp and along the old Francistown road.

No poisonous plants have been observed in, or were reported from the study area.

Production systems

Three major types of livestock production systems were observed in the planning area:

- extensive grazing of a flock of goats on communal land around the villages
- extensive grazing of a small cattle herd on communal land around the villages
- extensive grazing of a medium sized herd around a cattlepost on communal land

EGv Extensive grazing of a flock of goats around the villages

Individual farmers possessing goats let them graze freely around the settlements during the day. At night the animals are kraaled near the compound for protection against predators (hyenas and jackals). Goats are usually kept for subsistence meat and cash from occasional sales.

The Agricultural Statistics 1990 (CSO, 1991) reports the following figures for the Ngamiland East District over the period (1979-1990): birth rate 83%, death rate 26%, offtake rate 8%.

There are two active smallstock farmer groups in the AEA, one in Mawana and the other in Xhana. The objective of these groups is to improve smallstock management by carrying out the management operations recommended by smallstock extension officers and Veterinary Assistants. The group activities include dosing of animals for internal parasites, dipping for external parasites and vaccinations for specific diseases like pulpy kidney and pasteurellosis. The groups were funded through the AE-10 scheme. Each group constructed a crush and a diptank. The groups, however, do experience financial and management problems.

ECv Extensive grazing of a small cattle herd around the villages

The vast majority of cattle owned is from the Tswana breed. Herd sizes differ and for farmer grouping purposes, three classes of herd sizes have been distinguished: 1-10, 11-30 and ≥ 31 head of cattle. The cattle is not herded and range freely on communal grazing areas. The animals are only collected for watering and to be kraaled. Most cattle owners do not have bulls of their own. Breeding is uncontrolled and it is left to chance for breeding cows to meet bulls at the appropriate time. Only a few farmers purchased improved breeding stock (e.g. Simmental) from other farmers in the past.

First calving takes normally place after 3-4 years, and their after the calving interval is one year. Lactation is in most cases 3-6 months. Calving rate are around 50%, varying from 30-85%. Calve mortality rates are approximately 45%. Oxen are often sold at 4-5 years. The adult mortality rate is around 35%. Causes for cattle dying are diseases, predation and drought.

Often a two-daily migration takes place between grazing area and watering place. One day cattle is grazed in the area north of the settlements, while the next day it is driven to the river to be watered. Animals walk considerable distances, varying from 5-20km per day.

Cattle is kraaled every night to protect them against predators. Calves are usually kraaled separately from the rest of the herd. No supplementary feed is given; crop residue is eaten for a couple of weeks after the cropping season.

Cattle management is still largely traditional, with husbandry practices limited to castration, dehorning and occasional deticking. Almost all cattle is branded. Veterinary care is confined to the free government services; farmers take cattle to the communal crushes for free vaccinations. Other inputs in this type of production system are minimal; occasionally farmers buy salt licks, a water tank and a pump. Farmers expressed the need for a (communal) cattle dip, which does not exist in the planning zone.

Cattle is raised for subsistence (milk, meat and hides) and cash needs (buying of food, sending children to school etc.). Off-take figures are unknown, but are probably very low, in the order of magnitude of a few beast per year. This corresponds well with the 9% offtake rate mentioned in the Agricultural Statistics 1990 (CSO, 1991) for the Ngamiland East District.

The reluctance to sell cattle is so great, that even when facing a severe drought farmers would rather take the risk to see their cattle die, than selling animals. The only reason farmers give for this attitude is their fear to become poor. As most people in rural areas are not used to save money on a bank account, they fear to spend the money from cattle sales. It also appears, that farmers like to keep as many cows as they can, to ensure the survival of (a portion of) the herd in the event of a drought or for traditional purposes (prestige, "labola"/bride wealth, funerals, etc.). Another possible explanation could be, that the reluctance to part with cattle is related to the difficulty of earning a living from crop production.

Most families manage their cattle themselves; occasionally a herd boy is employed.

In the settlements of Mawana and Xhana a cattle syndicate was formed. The united farmers had boreholes drilled along the Boteti River for livestock watering. The Tawana Land Board can not provide the syndicates with a lease agreement as the boreholes have been drilled within 8 km from the riverbed (Land Board regulation). Without a Land Board certificate the syndicates are not able to obtain government support for equipping the boreholes.

This production system is often combined with the extensive grazing of goats. Frequently some donkeys are kept for draught power.

<u>ECc Extensive grazing of a medium sized herd around a cattlepost</u>

Generally this production system is characterized by a somewhat improved management system and some more inputs than the previous system. Cattleposts are located in the sandveld.

Herds are usually consisting of 50-200 beasts. Often an improved bull is owned. First calving takes place at three years, followed by a calving interval of one year. Calving rates are approximately 60%. Calve mortality rates are relatively low: 15% (range 10-20%). Oxen are sold, when 4 years old. The adult mortality rate is 20%.

The Agricultural Statistics (CSO, 1991) give the following average herd composition figures (as percentage of the total herd) for the Ngamiland East District: bulls 1.2%, oxen 8.1%, cows 47.1%, steers 10.8%, heifers 10.9% and calves 21.8%. The offtake rate amounts 9% per year.

Cattle is usually not herded, only kraaled at night. The animals are watered a little bit in the morning, go out for grazing during the day and return in the afternoon, when they get more water. Borehole water is usually slightly saline in this area. The animals graze around the cattlepost and cover distances upto 10-20km a day. Cattle from one cattlepost was found to walk 17km to the west (and back, 34km in total), to Mathlapaneng village, to drink from the Thamalakane River (when flooded).

Suckling is supervised; calves and cows graze separately. Cows are milked in the morning and evening, producing up to a maximum of 3-5 liters/day. Sour milk is produced; the ratio fresh to sour milk is 2:1. Sour milk is consumed by the family and sold in Maun.

Almost all cattle is branded. Dehorning and castrating is practiced, as is the use of tick grease and regular spraying (upto once a month) with Acarinde (double benex) with a knapsack sprayer. Horses, donkeys, sheep and goats are sprayed at the same time. The Veterinary Department visits the cattleposts and administers free vaccinations in the cattle crushes belonging to the cattleposts. Occasionally salt licks are provided, but normally no supplementary feed is given.

Often a herdsman and some assistants are employed at a cattlepost. Apart from a cattle crush some simple dwellings have often been constructed to house the workers and store equipment and supplies. The well or borehole is normally equipped with a diesel pump and a water tank and trough.

Some cattlepost owners do share or sell water from their wells or boreholes with other cattle farmers. Prices paid for this service are unknown.

Frequently a flock of goats is kept at the cattlepost, besides some donkeys and horses.

4.4.3.5 Veld product collection

Nearly all households in the planning area utilize at least one type of veld product on a regular basis. The farm survey learned, that 38% of all households gathers one or more veld products for sale. The most regularly collected veld product for sale, by 31% of the selling households, is "lethaka" (reed), followed by "mogwana" and "moretlwa" (*Grewia* berries), by 19% of the selling households, and "rothwe" (wild spinach), by 12% of the selling households. Thatching grass, fish and "tswii" (water lily tubers) is collected by 6%, 6% and 4%, respectively.

It are usually the women and children in the poorer households, that are involved in the collection, processing and sales of veld products. An exception is made by the felling of trees for fencing, construction or fuelwood, which is a male activity.

Veld products have a wide range of uses, including the use as building materials (river reed, mothebe, thatching grass, *Sansevieria*, mopane), food (fish, rothwe, water lily, *Grewia*) or fuelwood. The grapple plant (devil's claw), used for medicinal purposes, occurs in unknown quantities and is so far not being exploited in the planning area.

The supply of most of these veld products is influenced by the rainfall situation in a given year. The availability of rothwe, *Grewia* fruits and thatching grass depends directly on the rainfall in the area and is low in dry years. Products from the Boteti River depend on the river flow and are less dependent on local rainfall.

A conflict of interest exists between the gathering of veld products like rothwe and *Grewia* berries (usually December - March) and crop production related activities.

4.4.3.6 Farming systems

As shown in Section 4.4.3.4, 67% of all households owns cattle, while 82% owns cattle and/or goats. In an average rainfall year, virtually all households are engaged in crop production activities. So, the majority of the population practices a mixed farming system. Input levels are low to medium and produce (grain and meat) is mainly used for subsistence purposes.

For most households two main linkages exist between the crop and the livestock production systems. The first connection is related to the keeping of donkeys for draught power. Unless used for transport, generally not much care is taken of donkeys. They roam around freely on the communal grazing areas and are only collected around ploughing time. The second linkage concerns the grazing of crop residue by livestock and smallstock. Immediately after harvest the animals are allowed in the fields to eat the stover. No effort was recorded to grow fodder crops, to improve pastures or to make hay.

The farmer groups identified in Section 4.4.2 practice the following farming systems. Only the major production systems are used for characterization. Most farmers have access to similar soils, making the factor land the same for all farmer groups.

Farmer Group P1: Low input, subsistence mixed farming system I
production systems:
1. arable crop production (small area cultivated < 2 ha)
2. livestock production (small herd/flock < 10 ceq.[1])
3. collection of veld products

Farmer Group P2: Low input, subsistence mixed farming system II
production systems:
1. arable crop production (large area cultivated > 2 ha)
2. livestock production (≥ 4 donkeys and small herd/flock < 10 ceq.)
3. collection of veld products

Farmer Group W1: Medium input, subsistence mixed farming system I
production systems:
1. arable crop production (varying area cultivated)
2. livestock production (≥ 4 donkeys and medium sized herd/flock 11-30 ceq.)
3. collection of veld products

Farmer Group W2: Medium input, subsistence mixed farming system II
production systems:
1. arable crop production (varying area cultivated)
2. livestock production (≥ 4 donkeys and medium sized herd/flock 11-30 ceq.)

Farmer Group R1: Medium input, subsistence mixed farming system III
production systems:
1. arable crop production (large area cultivated > 2 ha)
2. livestock production (≥ 4 donkeys and medium to large herd/flock ≥ 31 ceq.)

Farmer Group R2: Medium input, subsistence mixed farming system IV
production systems:
1. arable crop production (small area cultivated < 2 ha)
2. livestock production (≥ 4 donkeys and medium to large herd/flock ≥ 31 ceq.)

The individual production systems will be evaluated in Chapter 6.

4.4.4 Infrastructure and communications

4.4.4.1 Major roads, power and water supply and other services

The Chanoga AEA is a typically rural area with only basic facilities. Maun functions as service center, where schooling facilities, health care, postal services & telecommunication, Land Board & Council, shops & markets, and air services are reasonably well established.

Roads

The main Nata-Maun road (tarring completed in 1992) runs east-west through the extension area. All villages/settlements lie close to this road and are therefore easily accessible. Other locations

[1] ceq. - cattle equivalent

away from the main road, like cattleposts and some lands areas are accessible through a network of dirt roads requiring 4x4 vehicles, donkey carts or horses. Maun is situated 30km west of Chanoga village, half an hour by motorcar and a day by donkey cart. Nata is located approximately 270km to the east.

The new Nata-Maun road meanders around the old calcrete road and at places follows the same alignment. The western, eastern and northern boundaries of the Chanoga AEA are formed by sandy cutlines.

Power

Parallel to the alignment of the old Nata-Maun road, but approximately 2km north, runs the powerline that connects Maun to the national grid. Non of the villages/settlements in the planning area are linked up to this power supply.

Water supply

The Boteti River is the main source of water in the extension area, supplying water for both livestock and domestic use. When the river dries up water can still be obtained from wells, dug in the river bed, though the supply becomes increasingly inadequate and unreliable.

It is the responsibility of the District Council to provide communities in recognized villages with water. The village of Chanoga is the only locality with piped water from a Council borehole, struck on the north bank of the Boteti River. Mawana, Tsibogolamatebele and Xhana are not recognized by the Council as villages. Domestic water collection in these settlements used to be a time-consuming task for most households. Water was collected from wellpoints in the river or from standpipes in Chanoga. Since mid 1996, Council placed water tanks in the three mentioned settlements, which are filled by a bowser on a daily basis. During the rainy season, water is often collected from pools along tracks.

Very few farmers have ALDEP catchment tanks at their lands. Cattleposts a long way from the river obtain their water from hand dug wells (often with a diesel pump) or boreholes. This water is sometimes saline and only suitable for livestock consumption. During the rainy season pans and depressions provide a temporary source of surface water for cattle and smallstock.

At Tsibogolamatebele a group of farmers formed the Thswaregano Water Development Group. The group applied for funds through ARAP and the Drought Relief programme to construct a pump house, a pipeline, a reservoir and two watering troughs. The project cost P 34,000 (1988). The government provided the equipment, while the group members contributed by clearing the alignment and digging the trench for the pipeline through a labour based drought relief project. After completion of the project, the group members were responsible for the running expenses and maintenance of the equipment. Water used to be pumped from the Boteti River (4 km south of the settlement) to the reservoir at the centre of the village for domestic use. On the edge of the village two troughs were placed, which were connected to the same pipeline, and used to water calves and smallstock. From mid 1993 the facilities have not been used, as the Boteti River had dried up. The Group has fallen apart since, as approximately 20 members left with their cattle for the Shorobe area (to the north) in search for a better grazing and water situation.

Education and health

The District Council is responsible for providing education and health services to communities in villages. Chanoga has a primary school, which is mainly attended by children from the village. Children from the surrounding settlements often obtain their education in Maun, where they stay with family members. Several junior and one secondary school are situated in Maun.

In the village of Chanoga, a clinic was built. Xhana and Mawana are supported by mobile health stops at the rate of one visit a month by health workers. A store and consultation room were built in each of these settlements through the VDCs under the labour based Drought Relief programme. Undernourished children under the age of six and expectant mothers obtain food rations at the clinic or mobile stops. For special treatments patients are referred to Maun General Hospital.

Telephone

Microwave towers for telecommunication have been erected in the planning area in the early 1990s, mainly to serve Maun and the western part of Ngamiland. Only in August 1996 several telephone connections have been made in the village of Chanoga.

4.4.4.2 Agricultural services and institutions

An AD and a Veterinary Assistant (VA) are based in the village of Chanoga. The AD covers the entire planning area, while the VA covers the portion of the planning area south of the old Nata-Maun road. The northern part is included in the Matlapaneng Veterinary Extension Area.

The Veterinary Department provides free compulsory vaccinations for the following cattle diseases: Anthrax and Black leg (January/February and October/November), Foot & Mouth Disease (April and September) and Brucellosis (May). Vaccine is available against lumpy skin disease, African horse sickness, equine influenza and newcastle disease (poultry). A rabies campaign for cats and dogs is held yearly (June).

An Artificial Insemination (AI) Camp is located at Makalamabedi, just east of the study area. Due to the lack of water in the Boteti River, the Camp is not operational since 1992. At Nokaneng (approximately 200 km northwest of Chanoga) the only operating AI Camp in the entire Ngamiland District is situated. The Veterinary Department also maintains a mobile AI service throughout the District, where vets teach farmers how to conduct AI themselves.

The Makalamabedi and Shorobe Quarantine Camps and the Makalamabedi Botswana Livestock Development Corporation (BLDC) Ranches are located east and north of the AEA (see Figure 6).

The Chanoga AEA is further serviced by the District Agricultural Office (Ngamiland East), the Regional Agricultural Office, the Regional Agricultural Research Office, the Animal Health and Production (Veterinary) Department and the Department of Cooperatives (all Maun Region). At all these offices subject matter specialist are available for extension to farmers.

In Maun the following agriculture related institutions can be found: depots of the Botswana Agricultural Marketing Board (BAMB) and the Botswana Cooperative Union (BCU), a Livestock Advisory Centre (LAC), a Botswana Meat Commission (BMC) Abattoir and a branch of the National Development Bank (NDB).

4.4.4.3 Markets for agricultural products

Maun is the market centre (both formal and informal) for the planning are. A BAMB depot, a BCU branch, supermarkets, a BMC Abattoir, local butcheries and the traditional market are located there.

No formal markets have been established for smallstock and veld products.

Most households of the Chanoga AEA are to a greater or lesser extent integrated in the market economy. Links with markets comprise of occasional sales of crop produce, (sour) milk, livestock and smallstock or veld products on the one hand and of the purchase of inputs, services and consumer goods on the other hand.

Crop marketing

The official channel for marketing of grain surpluses is through the BAMB depot. Not many farmers in the Chanoga AEA reach a production high enough to sell to BAMB. Additionally, BAMB prices are relatively low and transport of the surplus to Maun may lead to a problem.

Crop produce that is marketed includes watermelons, sweet reed, green mealies, beans and grains. Many sales take place on traditional markets and through informal transactions between buyers and sellers (individuals or wholesalers). Bartering of produce is still common amongst people in the village and settlements in the planning area.

Livestock marketing

BMC, BLDC, butcheries and individuals form the market for cattle. Small farmers prefer to sell their cattle to butcheries or individual buyers, because they immediately receive cash. This is important to this group of farmers, since they mostly sell their livestock to cover immediate expenses. The Agricultural Statistics 1990 (CSO, 1991) give the following figures for the ratio of cattle sold in the Ngamiland East District, to: BMC 55.8%, BMC + others 7.6%, another farmer 15.7%, traders 6.4% and local butcheries 14.5%. The farm interviews suggest, that this last figure be higher in Chanoga AEA, while the BMC figures seem lower in Chanoga.

Selling to BMC requires cattle to be driven to one of the Quarantine Camps (Makalamabedi or Shorobe), and herded inside the Camp for 21 days (by the owner or hired labour) before slaughter. Payment only follows later.

Under normal circumstances, before the cattle lung disease, Makalamabedi Quarantine Camp operated as follows: On Thursday and Friday cattle was brought in by truck from Ngamiland and Central District. Cattle stayed for 21 days in the Camp; the animals were not treated, only checked for FMD. The Quarantine Camp consists of two paddocks with a total capacity of 1700 beasts. No rotational grazing was conducted. On Monday, Tuesday and Wednesday cattle was trucked to the BMC Abattoir at Maun.

The Makalamabedi Quarantine Camp is supplied with water from three borehole on the north bank of the Boteti River; water is pumped into reservoirs along the river and then piped to the Camp. Bowsers are used in times of water shortage.

Trekked cattle from the Ngamiland and neighbouring Districts was taken to the Shorobe Quarantine Camp, were it stayed for 21 days, before it was trekked to the Makalamabedi Quarantine Camp (42km in one day), from where it was trucked to BMC. Trekking from Maun to the Shorobe Quarantine Camp (approximately 60km) takes two days.

The BLDC operated as follows: farmers trekked their cattle to the BLDC crush just outside the Makalamabedi Quarantine Camp (west of the Camp, near the main road). At the crush BLDC bought the cattle of the farmers. From here cattle went into the Makalamabedi Quarantine Camp for 21 days, before being transferred to the BLDC Ranches, located adjacent to the Camp on the eastern and northern side. At the Ranches cattle was fattened and from there sold to individual farmers and government.

At the moment of writing this chapter (mid 1996) BLDC had suspended the purchase and sales of livestock at their Makalamabedi Ranch, because of a lack of water on the ranch and because of the outbreak of cattle lung decease. The BLDC Ranches will probably be stocked with cattle, that will be used to compensate affected livestock owners throughout the entire Ngamiland District.

The BMC abattoir at Maun does not process any smallstock. In fact there is no formal smallstock market in Maun and most goats are sold to occasional buyers.

Veld product marketing

The market for veld products is undeveloped, although there seems to be no shortage of buyers. River reed ("lethaka") and thatching grass, for instance, are cut and stored conspicuously outside the compounds for interested buyers. *Berchemia* berries ("motsintsila"), *Grewia* berries ("mogwana" and "moretlwa"), wild spinach ("rothwe") and waterlily tubers ("tswii") are sold at the traditional market in Maun. When the market is flooded with *Grewia* berries, sellers dry and store the berries and release them onto the market in winter, when supply is low. Often sold in the villages, or used as payment in kind for casual labour or for bartering, is traditional beer ("khadi"), made from *Grewia* berries. Also informally sold within the rural communities and in Maun are baskets, woven from palm ("mokola") leaves, mats ("mabinda"), woven from flattened reed and fuelwood (mainly "mopane").

Potential markets

The District capital Maun (30,000 inhabitants) and the Ngamiland District as a whole (approximately 100,000 inhabitants) form potential markets for diverse agricultural produce, varying from grains, horticultural products, to chickens, fish and game meat. Much of these commodities are imported from South Africa and supplied over a distance of 1400km. One reason for import is, that local produce reaches the Maun markets in an erratic way. The main product from local suppliers, that was in abundance and had a constant supply, was meat; this is to a lesser extent valid for chickens.

4.4.5 Data for financial analyses

To assess the financial viability of the present and potential production systems (see Chapter 6), the following information is collected (prices given were valid during the 1994/95 cropping season):

Crop production

INPUTS

seeds:	cowpeas *Blackeye/Tswana*	Pula 5.62 per 10 kg	BAMB[2]
	groundnut	Pula 5.62 per 10 kg	BAMB
	maize *Kalahari Early Pearl*	Pula 3.36 per 10 kg	BAMB
	millet	Pula 3.36 per 10 kg	BAMB
	sorghum *Segaolane*	Pula 3.36 per 10 kg	BAMB
	sunflower *Russian # 4*	Pula 3.58 per 10 kg	BAMB
fertilizer SSP[3]		Pula 28.55 per 50 kg bag	BAMB
fertilizer 2:3:2 NPK[4]		Pula 34.95 per 50 kg bag	BAMB

farm labour	family labour is not taken into account in financial analyses
hired labour	opportunity cost Pula 6.00/day, based on Drought Relief programme
animal draught power	when supplied by the farmer, no costs are included
Alphametrin	Pula 20.00 per ha for one spraying session[5]

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[2] BAMB producer prices for the Maun Region

[3] Single Superphosphate (10.5 % Phosphorus)

[4] Compound fertilizer consisting of Nitrogen, Phosphorus (9.4 %) and Potassium

[5] Based on unit price of Pula 160.00/liter (Clover Chemical Ltd, reported in Kristensen & Molelo, 1996)

VALUE OF PRODUCE

cowpeas, purple and other	Pula 41.90 per 70 kg bag	BAMB[6]
cowpeas, black eye	Pula 59.45 per 70 kg bag	BAMB
	Pula 130.00 - 150.00 per 70 kg bag sold locally	
groundnuts (shelled), grade 1 and 2	Pula 72.00 per 70 kg bag	BAMB
maize, white grade 1	Pula 33.50 per 70 kg bag	BAMB
	Pula 30.00 - 40.00 per 70 kg bag sold locally	
	1 bag bartered for 1 goat	
millet	Pula 31.80 per 70 kg bag	BAMB
sorghum, red and white grade 1	Pula 31.80 per 70 kg bag	BAMB
	Pula 50.00 - 60.00 per 70 kg bag sold locally	
sunflower, grade 1	Pula 19.25 per 40 kg bag	BAMB
jugo beans	Pula 45.80 per 70 kg bag	BAMB
melons	Pula 1.50 per kg	street venders
sweet reed	Pula 0.50 - 1.00 per stalk	street venders

DROUGHT RELIEF SUBSIDIES[7]

Ploughing	Pula 120.00 per hectare
Rowplanting	Pula 50.00 per hectare
Free seed	10 kg pockets of millet, maize or sorghum

Livestock production

INPUTS

Costs of fencing, veterinary care, equipment and supplementary feed have not been assessed, but should be included when a discounted cash flow analysis is prepared.
Herdsman at cattlepost Pula 200.00 per month

VALUE OF PRODUCE

tea cup of sour milk	Pula 0.50
goat's hide	Pula 1.50-3.00 depending the grade
cattle sold to BLDC	Pula 1.50 per kilogram
cattle sold to BMC[8]	Pula 435 per 100 kilogram grade 1
	Pula 395 per 100 kilogram grade 2
	Pula 365 per 100 kilogram grade 3
	Pula 333 per 100 kilogram grade 4
cattle sold to local butchers	Pula 450.00 per beast (ranging from Pula 200-700)
goats sold informally	Pula 50-100

Prices offered by butcheries depend on bargaining. BLDC sells cattle to the public at a fixed price of Pula 650.00 per beast. The BMC price structure is based on the grade of cattle, which changes during the year.

The opportunity costs of investments in farm buildings and implements are not taken into account in the financial analyses for both crop and livestock production.

[6] BAMB producer prices for the Maun Region

[7] The subsidies are issued to individual farmers for a maximum of 5 ha or 40 kg

[8] Prices for May 1995 from BMC Abattoir Francistown

DROUGHT RELIEF SUBSIDIES[9]

a) Borehole drilling component	-	grant of 60% of costs of drilling for individuals and syndicates having 61-200 cattle
	-	grant of 40% of costs of drilling for individuals and syndicates having more than 200 cattle
b) Equipping component (syndicates only)	-	each syndicate member should not own more than 60 cattle
	-	each syndicate will be assisted up to a maximum of P 20,000
c) Livestock feed subsidy	-	the following items are sold at 50% of the normal price at LACs throughout the country: dicalcium phosphate, drought pellets, cattle blocks, winter licks and coarse salt.

Veld products

VALUE OF PRODUCE

baskets	varying in price, starting from Pula 10.00
khadi	Pula 0.50 per mug, often used for payment in kind or bartering
fuelwood, mainly mopane	Pula 60.00 per donkey cart load of approximately 2m^3
Grewia berries (dried)	Pula 1.00 per mug
lethaka	Pula 1.00 per bundle with a diameter of 1 mug
motsintsila berries (dried)	Pula 1.00 per mug
rothwe (boiled)	Pula 1.00 per tea cup
	Pula 0.50 per spoon
thatching grass	Pula 1.00 per bundle with a diameter of 20 cm

[9] Programme put in place in October 1995

5. LAND USE PROBLEMS AND SUGGESTED OPTIONS

This chapter discusses the problems encountered in the main production systems practiced in the Chanoga AEA. Explanations are given for the poor performance and suggestions are formulated for improvement of the present production systems. In Chapter 6, the suggested options will be evaluated on physical suitability, financial viability and sustainability.

5.1 Low rainfed arable crop yields

5.1.1 Constraints

5.1.1.1 Constraints related to the natural environment

a) Adverse climate
Botswana's climate, characterized by unreliable rainfall (low amounts, erratic in occurrence and varying from season to season), alternated with dry spells, attributes to sub-optimal yields. Isolated thunder showers accompanied by strong winds and/or hail can cause considerable crop damage (lodging and shredded leaves). Late planted crops run the risk to be affected by frost in June.

b) Low soil nutrient status
Most soils in the planning area have a sandy texture and a naturally low fertility level: low organic matter content of the topsoil and low Phosphorus, Nitrogen and Potassium levels. Crops are grown every year, but fertility maintenance does not form part of the management systems. Crop residue is normally not ploughed back in the soil, nor is kraal manure or inorganic fertilizer regularly used. The use of kraal manure is often hampered by transport problems. The same applies for inorganic fertilizer, which, in addition, is not affordable for many households.

c) Land degradation
Wind erosion and top soil nutrient depletion and loss of structure are the most notorious signs of land degradation, affecting crop performance.

5.1.1.2 Constraints related to crop management

a) Choice of crop
Although maize is the most frequently grown crop, due to its low drought resistant nature, low yields and many crop failures have been reported.

b) Low labour productivity
Management operations are often carried out with 3-4 people, resulting in a low level of labour efficiency. The necessary minimum is 2 people for all three operations; one to control the implement and one to control the draught animals. Crop trials during the cropping season 1994/95 have shown, that in Ngamiland East on average 109.4 manhrs/ha was spent on fertilizing (8.4), ploughing (63.5), harrowing (12.5) and rowplanting (25). If the actual hours spent on these operations is calculated for 2 people (a more efficient use of human resources), then an average of 75.4 manhrs/ha should be spent. Assuming a working day of 6 hours (from 6 am to noon), it would take 2 people 6.3 working days to finish one hectare (Bekker, 1995). Labour shortages occur, especially in female headed households, for typical male activities as ploughing, harrowing and planting, while in most types of households labour shortages are common for the time consuming activities of weeding and bird scaring.

c) Poor crop husbandry
Over the past years a decrease in area cultivated as compared to the baseline area has been observed. This is accompanied by a subsequent decrease in production. The main reason for this development is, that farmers are losing interest in rainfed farming due to the unreliable rainfall over

the past decade. Despite this fact, still a large discrepancy exists between the area ploughed and the area harvested. A threefold explanation can be given for this phenomenon: 1) planting takes traditionally place too late, increasing the chance on a crop failure, 2) pest and diseases attribute to a reduction in yield and 3) the drought relief ploughing subsidies seem to encourage ploughing operations, rather than to increase the production.

Late land preparations
Too late migration from Maun to the lands attributes, for part of the farmers, to late preparations for the cropping season and consequently missing or intentionally skipping the first (two) planting opportunit(y)/(ies). A late start of the ploughing and planting operations is often caused by a temporary lack of labour. After a sufficient rainfall event, farmers often wait for 1-2 days with ploughing/planting, in order to give the rain water the chance to infiltrate and properly wet the soil.

Apart from one or two days lost for looking for draught animals, the long time spent per hectare on land preparations explains the delay between the end of the rainfall event and the day of planting. A further delay is sometimes caused by the fact, that farmers do not work on the lands on either Friday, Saturday or Sunday, due to traditional and religious reasons. Time is also lost due to social obligations as meetings, marriages and funerals.

In general, late planting (DEC3-FEB2), is often a result of low dedication towards rainfed cropping. Priority to other occupations causes low production, through late planting.

Often in Botswana, farmers give as excuse for late planting the reason that their draught animals are in a bad shape at the beginning of the rainy season. From the on-farm trials during the 1994/95 cropping season, it appeared that most trial plots were ploughed within six days after the identified planting rain (Bekker, 1995). In many cases part of the farmer's own field was ploughed during the same period as well. Based on this observation, it is hard to accept the argument of weak draught power as main cause for a delay in starting to plough/plant. It should be remarked, however, that due to the weakness of the draught animals, ploughing and planting operations take more time in the beginning of the season, than later on. Frequently, only the morning is used for ploughing/planting at the beginning of the season, leaving the animals enough time to recuperate, feed and drink. Later in the season, however, the animals are also used in the late afternoon.

Other reasons for untimely operations are the dependency on tractors for ploughing and the lack of implements.

Ploughing / Harrowing
Improper seedbed preparation (irregular ploughing, no harrowing), often leads to uneven planting depths, resulting in poor emergence and uneven plant stands (in combination with no gap filling and/or thinning) and finally to low crop yields.

Planting and seed rates
Broadcasting of a seed mixture, which is commonly practiced, seems a good strategy for risk spreading during seasons with below average rainfall. However, it usually leads to irregular (spatial) distribution of seeds and variable planting depth, resulting in uneven crop stands. Bird and insect damage to seed is typical, just after planting.

Planting is a crucial operation and the use of a row planter demands special care and accurateness of the operator. During the on-farm crop trials various problems with row planters were observed (Bekker, 1995). The main constraint was a temporary blockage of the seed outlet and hence uneven seed droppings. Often grass tufts and damp soil clods were dragged along by the planter for a couple of meters, blocking the seed outlet and thus attributing to an uneven plant stand. Irregular surfaces caused by furrows, also led to varying speed and direction of the planters, resulting in uneven seeding rates. At times, high amounts of sorghum seed were dropped, e.g. seeding rates up to 40 seeds/m^2 have been observed, which would have resulted in a plant density of 400,000 plants/ha, if all seeds would have emerged.

For the same trial programme, DAR recommended a sorghum seeding rate of approximately 3 kg/ha in order to achieve a plant density of 15,000 plants/ha. Most trials around Maun, however, reached plant densities below 5000 plants/ha. Based on seed counts, 3 kg of sorghum seed should be enough to reach a plant density of 100,000 plants/ha (at 80% germination rate). The discrepancy can be explained by a combination of possible constraints: planter problems, uneven dropping of seeds, damaging of seeds or a germination potential less than the guaranteed 80%.

Despite the observed problems with rowplanters, no gap filling and thinning operations are carried out. If no thinning is done, the competition for soil moisture is maintained, restricting the growth of individual plants and possibly leading to lesser grain yield per plants or failure to develop heads all together. A possible reason for not carrying out these operations is their time consuming nature.

Weeding is often done too late, not effectively or not at all. A labour shortage and too large fields are regularly debet to improper weeding operations.

Pest and disease factor

Sorghum and millet plants are prone to bird damage during the grain filling and early ripening stages, when the grains still contain a high moisture content. Bird damage (mainly by Quelea birds) depends generally on the amount of effort put into scaring. Where not enough labour is available, or when other domestic activities get priority, considerable damage occurs; observations showed 80-100% of the grains on individual heads had been picked towards the end of the ripening time. In a poor rainfall year like the 1994/95 season, an additional hazard was formed by local birds (like pigeons), which attacked crops as soon as seeds had formed, due to the lack of seed bearing grasses and berry forming shrubs in the surrounding bush. Other pests like aphids, armyworm, stalkborers, bollworm and corn crickets occur regularly and can greatly affect crop yields. Farmers have no easy access to chemicals to fight these pests. Shops are far (Maun) and do not stock many chemicals. The Plant Protection Division is at times warned late through the AD. Plant Protection Officers can only react slowly due to commitments in many corners of the District. Poor fencing often causes crop damage by livestock entering in the fields.

5.1.1.3 Constraints related to institutions, location and poor market facilities

a) Low adoption rate of extension messages and use of assistance programmes

In years of declared "drought", Agricultural Demonstrators spend must of their time with administration related to ploughing subsidies. The ADs' tasks are not made easier due to difficulties with transport, a not differentiated package of recommendations and the age gap between them and the average farmer. Because of the high age of farmers, ADs need a considerable amount of persuasive power, while the drive for innovation is lacking in many households. Illustrations of the low adaption rate of extension messages are the small percentage of farmers conducting harrowing, rowplanting and cultivation operation. A cultural reason attributes to the above. Broadcasting is traditionally seen as a female activity, while harrowing, rowplanting and cultivating are considered as male activities. They also involve more time and labour. More extension and a change in cultural pattern are needed before these operations become common practice.

Several reasons can be given for the low use of the ALDEP programme:

- the down payments are too high
- lack of proper knowledge of the advantages of the programme
- the administration is too complicated; either due to a lack of support by the AD or illiteracy
- no Land Board certificate, so not eligible to ALDEP packages
- the progressive eligibility to packages; no draught power owned, not eligible to a plough; no plough, not eligible to harrow/cultivator/planter/scotch cart etc.
- lack of labour to cut poles (as contribution) for (group) fencing

The introduction of drought relief packages (ploughing subsidies and free seed) made many farmers dependent on government assistance. Ploughing subsidies form a large portion of the annual cash income for the resource poor farmer groups. Late distribution of seeds has led to missing of planting opportunities. The government assistance programmes provide insufficient incentive to increase the arable production, as they lack a component of producer subsidies.

b) Distance from main suppliers
Although close to Maun, farmers do not always have (timely) access to required inputs. The location of Maun, approximately 950km by road northwest of the nation's capital Gaborone, does not guarantee the supply either. Seeds, fertilizer, pesticides and livestock related accessories and medicines are not always abundantly available. Prices are often higher than in the south of the country caused by mark-ups due to the high transport costs. This situation has a bearing on the rate of adoption of extension messages.

c) **Grain storage** and poor **marketing facilities**
Threshing and on-farm grain storage techniques are usually basic, resulting in considerable post harvest losses. No lock-up store for grain surpluses exists in the AEA and the BAMB depot at Maun is too far for many farmers. BAMB producer prices are low and not compatible with local traders.

5.1.2 Suggested options

5.1.2.1 Improved soil management

a) **Fertility maintenance**
The use of kraal manure, inorganic fertilizer, ploughing in of crop residue or agroforestry and mulching techniques could lead to improvement of organic matter content and structure of the topsoil, AWHC and soil nutrient levels. The government could, instead of giving farmers cash as a ploughing subsidy, provide farmers with assistance in kind, like fertilizer. As phosphorus is the most limiting soil nutrient, Single Superphosphate (SSP) fertilizer is to be recommended above a compound fertilizer. It contains more phosphorus and is cheaper than 2:3:2. When fertilizer is used a second weeding operation should be recommended.

b) **Wind breaks**
To prevent wind erosion multipurpose hedges and trees could be planted in and along (portions of) the fields to break the erosive power of storms.

5.1.2.2 Improved land management

a) **Cultivation on better soils**
Although already practiced to a large degree, it is recommended to concentrate rainfed arable farming on the slightly more clay rich soils on the slopes of depressions. Farmers should be warned for shallow soils due to an impeding petrocalcic horizon, which is often found close to the surface in the bottom of depressions.

If farmers have access to a field, it is recommended to plough and plant in the molapos. A harrowing operation is advised. Even under rainfed conditions, molapo fields have a good potential.

b) **Cultivating smaller areas**
In order to increase the labour productivity, alleviate labour shortages and minimize crop damage and failure, it is recommended to concentrate efforts on small areas. Depending on the labour availability, 1-2 or 2-5 ha can be advised. At smaller fields rowplanting can be carried out with donkeys or hand hoe. In combination with timely operations, proper crop husbandry and production subsidies, the cultivation of smaller areas can improve the ratio area ploughed/area planted and can lead to higher production figures.

c) **Shifting over field**
As fields are normally much larger than the area cultivated each year, it is recommended to shift the cultivated patch over the entire field, thus including a fallow period in the farming system.

5.1.2.3 Improved crop management

a) **Improved crop husbandry**
Timely migration from Maun to the lands areas and timely preparations for the start of the cropping season (looking for donkeys, inspect implements, huts, fence, collection of seeds etc.) are advised. Farmers should try to be ready for ploughing/planting by November 20.

Draught power
If 4 donkeys are possessed, operations should be carried out with two alternating span; one span in morning and one in the afternoon. In this way each span has enough time to recuperate and the time used for ploughing/planting is reduced.

The introduction of small mechanized draught power in the form of handheld toolbars (2 wheelers) could be considered to speed up the plough/planting operations.

Proper timing of operations
Timely planting (from the third dekad of November/NOV3 till the third dekad of December/DEC3) forms the best protection against dry spells. Crop trials (Bekker, 1995) have illustrated the importance of a minimum of 20mm of rain during the establishment phase of the crop. This ten day period just after germination, seems to be crucial for the crop development. When established well, the small plants are more resistant to possible dry spells. The second advantage of timely planting is, that the crop can be ripening in April. This coincides with the arrival of flocks of Quelea birds, so that bird damage could be minimized.
Before rowplanting, a harrowing operation should be introduced, to smooth the surface and to achieve a uniform planting depth, which is a prerequisite for a homogeneous plant stand.

Rowplanting in combination with a crop rotation (grain crops alternated with legumes) will improve crop yields. Appropriate plant densities are advised. In general, it is recommended to keep plant densities low. Even in below average rainfall years, plants in a small population will have the chance to develop properly and produce large heads and consequently a high grain weight per head or per plant. An even row spacing and in-row plant spacing will reduce competition for available soil moisture. Accurateness in planting, and where necessary, gap filling or thinning should be carried out.

Timely weeding (30 days after planting, or when weeds have reached knee height) should be conducted, if not already done and will attribute to higher crop yields.

In order to reduce damage, more effective bird scaring techniques should be used. If well controlled, bird damage can be kept to a maximum of 10% of the grains of each mature sorghum head. Examples of methods observed in other districts are: scare crows, plastic bags on the stems or covering the heads, strings with tins filled with pebbles around the field and early harvesting and drying of heads on racks near the compound.

b) **Alternative management practices**
Especially on sandy soils a spreading of the land preparation operations could be considered. Operations like fertilizing and ploughing can be carried out before the first planting rain. Immediately after the first planting opportunity fields can be harrowed, followed by planting, and thus gaining valuable time and creating optimal conditions for germination and plant establishment.

The option of "dry ploughing/planting" on sandy soils brings all operations forward, including planting, and creates more flexibility for the farmer. This method of ploughing and planting before the first planting rain, is practiced all over the country, but at a very limited scale. By ploughing, possible weeds should die and do not re-emerge during the dry period before the first planting rain. If seeds are planted evenly at approximately 10cm below the surface, they should withstand the high topsoil temperatures and germinate after the first rainfall event of at least 20mm.

c) **Diversification/alternative crops**
The release at large scale of more drought resistant and early maturing (60-90 day ripening) varieties should strongly be considered.

With regard to a diversification of the presently practiced production systems, the use of alternative crops should be promoted. In Chapter 6, cash and fodder crops will be evaluated.

5.1.2.4 Improved institutional support

a) **Improved extension service**
When an arable Drought Relief programme is in place, the appointment of a separate payment coordinator should be considered. In that case, the AD can concentrate on proper extension work. To improve ADs' understanding of the natural resource base of their AEA, their offices should be equipped with basemaps concerning topography, soils, vegetation and present land use. In order for ADs to reach their clients, provision should be made for a means of transport. If no regular government transport can be guaranteed, loans for bicycles, motorbikes or cars should be made available.

Knowledge gaps should be eliminated through training programmes and more creativity in the delivery of extension messages. Recommendations on fertilizer dosages per soil type, available (alternative) seeds, pesticides, and marketing channels should be made available through kgotla meetings, pamphlets, training at the Nxaraga Rural Training Centre and field days. The content of government assistance programmes and how to qualify and apply should frequently be explained through radio messages and in simple brochures.

The farmers' record cards should be reintroduction and updated every time farmers' situations change. This will give at any point in time a clear picture of management-, production- and farming systems practised, in order to target recommendations to specific farmer groups.

The harmonization of Crop and Veterinary extension areas boundaries is recommended. This would facilitate ADs and VAs to cooperate and function as a multidisciplinary agricultural extension team and to share resources.

b) **Improved ALDEP programme**
Regarding the launch of ALDEP phase II, it would be wise to consider the following points:

- the awareness of the existence of the programme and the content of the packages should be increased
- the system of down payments and the administration involved should be reviewed
- better targeting of packages
- emphasis on the provision of essentials like draught power and plough on a household level, in order to make production units independent and better prepared to carry out timely operations
- technology transfer should take place per agro-ecological zone

c) **Redirection of arable Drought Relief funds**
When government decides to maintain arable drought relief subsidies, it should be considered to change the set-up of such a programme. Changes can be sought in the following directions:

- payment of the full ploughing subsidy, when ploughed before 1st January and 50% between 1st January and 15th February
- ploughing subsidies limited to 3 ha plus fertilizer and seeds
- reward several management operations separately, when carried out timely: ploughing, harrowing, (row)planting, weeding, pest and disease control measures
- redirection of funds to programmes aimed at higher production or investment in agricultural development
- creation of farmers' credit schemes, with government guarantee

d) Improved marketing channels
A lock-up store for grain surplus should be build in the AEA. In the same time the BAMB facilities should be improved. A mobile service should be created to bring inputs (implements, seed and fertilizer) to the farmers and to purchase farmers' surpluses from the lock-up store. The private sector should be encouraged to stock more inputs, including pesticides, in order for farmers to improve their crop husbandry practices and react swiftly on pest outbreaks.

5.2 Low molapo farming yields

Although molapo farming can only be carried out on a narrow strip in the floodplain, and it has not been practiced for some years, due to low water levels in the Boteti River, it is a production system, which has a potential for relatively high yields.

Molapo crop yields do normally not exceed 300-600 kg/ha. Some improvements in the management system, similar to those described above under rainfed arable farming, can be introduced. Reference is made to improved crop husbandry like timeliness of operations, a harrowing operation, rowplanting, and the use of appropriate plant densities (see Section 5.1.2.3). The use of fertilizer will generate higher crop yields as well.

5.3 Poor horticultural production and beekeeping activities

5.3.1 Low horticultural production

Horticultural production systems are not widespread. The main constraint is the unreliable supply of surface water for irrigation. Additional problems encountered are related to a lack of knowledge of vegetable growing and to pest and diseases (scarceness and price of chemicals).

If access to water could be assured through a wellpoint or borehole, horticulture could be practiced on a small scale for the household consumption or on a medium scale with a commercial motive.

For the individual farmer the establishment of a small vegetable patch (10x10m) in the backyard in combination with several fruit trees may be achievable. Compost, waste water, kraal manure and organic pesticides can be utilized in the garden. The produce will increase the variation in diet and improve the nutrition levels of the household members. Some of the produce might be sold and might generate some cash income.

Medium scale, market oriented horticultural production requires investment for equipment, improved management operations, including proper crop rotation, fertilizer use (initial gift and top dressing), proper plant care and protection.

5.3.2 Lack of beekeeping activities

Although natural bee habitats are present in the planning area (specially the riverine woodland along the Boteti River), the potential is not explored; no beekeeping is practiced.

As honey and wax have a good market value, the promotion of beekeeping activities could result in the set-up of several beekeeping projects.

5.4 Sub-optimal or unsustainable livestock production systems

5.4.1 Constraints

5.4.1.1 Constraints related to the natural environment

a) Low and erratic rainfall
The high interannual variation and the unpredictability of the rainfall, result in yearly changing range conditions, hence leading to unreliable biomass production figures.

b) Water shortage
In an area like the Chanoga AEA, without permanent surface water, the fluctuating water supply forms a constraint for livestock rearing. Shortages especially occur during the dry winter season, when natural pools fall dry and the water levels in the wellpoints in the Boteti River bed drop considerably.

c) Range degradation
Due to the location of the grazing area in the sandveld and the watering points in the Boteti River, and the daily migration of animals, overgrazing of a strip along the river has lead to serious range degradation. Infrequent veld fires in the grazing area attribute to a temporary shortage of edible biomass. Research by the Animal Production and Range Research Unit (APRU) of DAR has proven, that the higher the stocking rates, the more annuals and the less perennial grasses establish in the range (APRU, 1991). In areas with low stocking rates, the reverse counts. Dry Matter production of highly palatable grass species increases away from waterpoints, where grazing is limited. Dry Matter production of less palatable species, on the other hand, decreases away from waterpoints.

5.4.1.2 Constraints related to livestock management systems

a) Poor range management
High stocking rates along the Boteti river, due to livestock watering, and uncontrolled grazing and browsing result in range degradation. No herding takes place, nor range management in the form of paddocking or through drift fences.

b) Low input animal husbandry
The animal production systems practiced in the Chanoga AEA are typified by low and medium inputs. The main characteristics are uncontrolled breeding (few improved breeding stock purchased and hardly any AI practiced), high mortality rates (due to diseases, predation, especially around cattleposts, and drought, poor grazing and water situation), and low livestock care (minimal veterinary care, reliance on free government vaccinations and few supplementary feed or salt licks etc.). No fodder crops are grown, nor is hay made or are pastures improved. No communal cattle dip is found in the planning zone.

c) Low offtake rates
The majority of households considers cattle as the most important resource, providing wealth and status. However, cattle is often managed in an unprofitable way. This is illustrated by low offtake rates, resulting in:

- low investments in the cattle enterprise (e.g. few improved bulls purchased)
- large losses of animals in periods of drought, and
- very few benefits from livestock production used to improve arable production systems.

Rural households do not use bank accounts. Farmers fear to be unable to handle large sums of money, if they were to sell cattle regularly. From the farm interviews it also appeared, that farmers have the strategy to keep cattle in times of drought, hoping that a few beasts will survive and thus ensuring the possibility to rebuild their herds.

5.4.1.3 Constraints related to institutions and poor market facilities

a) Low adoption of veterinary extension messages
Apart from obtaining free, compulsory vaccinations (for sales of cattle to BMC or BLDC), very little extension advice regarding range management and animal husbandry practices is followed.

b) Poor Artificial Insemination services
Due to the closure of the Makalamabedi AI Camp, the AI services have been seriously affected.

c) Poor marketing facilities
No formal smallstock marketing channel for the planning area has been established. Occasional sales to individual buyers form the only outlet for smallstock. Despite lower prices obtained, farmers in need of cash prefer to sell their cattle to BLDC and local butcheries, instead of BMC. Due to the 21 day quarantine and the administration involved, sales of cattle to BMC is only interesting for slightly larger cattle owners, who do not need the cash to cover immediate expenses.

5.4.1.4 Constraints related to the CBPP outbreak

As stated before in Chapter 4, the cattle situation in Ngamiland has drastically changed due to the control measures taken as a result of the outbreak (in 1995) and spread over the District (in 1996) of Contagious Bovine Pleuropneumonia (CBPP), cattle lung disease. The government decided, that all cattle in the entire Ngamiland District had to be destroyed by end 1996. A cattle free situation will remain for an indefinite period. It is still uncertain, when restocking will start.

Due to the outbreak of the cattle lung disease and the following eradication measures, the Government decided to close down the BMC Abattoir in Maun for a period of 5 years.

5.4.2 Suggested Options

5.4.2.1 Improved land management

a) Improved water situation
Several options exist to alleviate the problem of unreliable water sources for livestock use. Boreholes could be drilled in the sandveld, the main grazing area. This option has the advantage of reducing the grazing pressure along the Boteti River. Disadvantages are the risk of hitting blanks or very saline water, the costs involved and the determination of which farmer group or community will obtain ownership and user rights of such new waterpoints.

Boreholes can also be drilled on the north bank of the Boteti River. Chances on fresh water are high; watering of livestock along the river though, does not tackle the ongoing range degradation in this fringe. Alternatively, water could be reticulated towards the sandveld, in a similar way as was designed for the Tshwaragano Water Development Group in the Tsibogolamatebele settlement. The bottleneck in this option is, that the Land Board, although not opposing the drilling of boreholes within 8 km from the river, will not issue a land right certificate. This will prevent the farmers to obtain government assistance for the equipment of such boreholes.

Lastly, more water catchment tanks and wells can be established in the lands areas, primarily to improve the condition of draught animals, during the cropping season. However, outside the cropping season, all livestock could benefit from these watering points and the grazing pressure along the Boteti River will be reduced.

b) Improved range management
Sustainable stocking rates should be pursued (see Section 6.4.2.1 for a range assessment).

Controlled grazing under supervision of herd boys in paddocks, communal grazing blocks or behind a drift fence should be considered. An improved layout of the communal grazing area, including paddocks and a drift fence could be designed. The idea of an east-west oriented drift fence separating the northern part of the grazing area from a southern block including the lands areas, was already discussed amongst the farmers in late 70s, beginning 80s. This proposal would reduce the grazing pressure along the Boteti River. Farmers seemed to support the idea, but could not agree on the formation of a group and individual contributions. At the time no solution was found for the unreliable water situation north of the projected fence. A possible fence should be combined with boreholes.

In the framework of the New Agricultural Policy (GOB, 1991) a fencing component has been formulated. It implies a change of land tenure. Individuals, farmer groups or communities are allowed to fence communal grazing land to increase livestock production and to improve range management practices. The recognized individual or associated cattle owners obtain the exclusive rights over the fenced areas. They will be eligible for government subsidies for fencing materials and water development.

In order to improve the nutrition status for all livestock, experiments could be set up with improved pastures. In fenced areas high quality grass species as siratro (*Macroptilium atropurpureum*), *Cenchrus ciliaris*, Babala millet, *Panicum maximum*, *Digitaria smutsii* and *Stylosanthesis guianensis* can be sown. Care should be taken through close monitoring, that the natural vegetation around the improved pastures is not changing with time.

Other possibilities to improve the nutritional intake of livestock are through the production of fodder crops (promising species are alfalfa or lucern (*Medicago sativa*), lablab bean (*Dolichos lablab*), and siratro (*Macroptilium atropurpureum*) and by feeding enriched crop residue. Crop residue should be harvested and ammonified by using a mixture of urea and water at a concentration of 10%. This forage could be fed to selected animals (pregnant cows, draught animals) during periods when grazing is scarce.

5.4.2.2 Improved livestock management systems

a) Improved herd management
In order to increase the productivity of the present livestock management systems more inputs are required. Controlled breeding through the purchase of improved bulls or AI should be considered. The animal health situation could be improved through more veterinary care, the use of supplementary feed (improved pastures, hay, fodder crops or enriched crop residue) and salt licks.

b) Increased offtake rates
If farmers can be persuaded by more extension to abandon the traditional method of storing wealth on the hoof, but increase offtake rates instead, livestock rearing might become a more commercially oriented and profitable enterprise.

5.4.2.3 Improved institutional support

a) Improved extension advice
Extension efforts should be increased with special emphasis on the improvement of animal health, herd composition and the increase of offtake rates.

b) Improved Artificial Insemination services
A borehole should be developed on the northern bank of the Boteti River, in order to supply the Makalamabedi AI Camp with water. After solving the water constraint, the Camp could be reopened and the AI services restored.

c) Improved marketing situation
Most households, particularly the poor with no or a few cattle, could benefit from a permanent and reliable market for smallstock. Farmers are likely to be less reluctant to sell goats than cattle. Especially during the time Ngamiland is cattle free, it could be considered to adapt the production line of the Maun BMC Abattoir to goat processing.

Concerning the marketing of cattle, the situation for especially small farmers should be improved. A locally based marketing group could be formed with assistance of an NGO to promote collective sales of cattle several times a year. Like proposed for BAMB, BLDC should engage itself more actively in the buying of cattle in the villages; this might increase offtake rates. Production incentives in the form of an offtake bonus could be considered by government.

5.4.2.4 Future cattle rearing after eradication of the CBPP

A unique situation will arise, when Ngamiland is cattle free; the district can become "model District" in cattle management. Land use planning should start soon, and include the following aspects:

- a range assessment, in order to estimate sustainable stocking rates
- a socio-economic study to investigate the readiness of farmers for the creation of cattle syndicates, in order to carry out the fencing component of the New Agricultural Policy
- the introduction of paddocking in large communal grazing area blocks through the use of drift fences.

5.5 Low use of veld products

5.5.1 Constraints

5.5.1.1 Constraints related to resource management

a) Burning and veld fires
The Boteti River channel is rich in clumps of "lethaka". It was observed though, that large sections with reeds were burnt down. Farmers accused strangers from outside the AEA of destroying this resource. In dry years the supply of reeds and thatching grass is limited. Occasional veld fires affect the stands of the last resource.

b) Indiscriminate logging of mopane trees and the use of ***Acacia*** trees for bush fences
Colophospermum mopane trees are regularly transported to Maun and sold as fuelwood and for construction purposes. Random felling of these trees should be regulated. Vegetation destruction takes place, as many farmers utilize branches of various *Acacia* trees to mend their bush fences, to protect their crops against livestock damage.

5.5.1.2 Constraints related to poor marketing facilities

Many households collect one or more types of veld products for subsistence use. Some marketing takes place in the settlements and in Maun. No formal marketing channel has been established as it is not worthwhile to travel to Maun to try and sell small quantities of veld products at the time.

5.5.2 Suggested options

5.5.2.1 Improved resource management

a) Improved protection and sustainable use of veld products
The awareness should be increased amongst the local population concerning the market value of many veld products and the need for protection of these resources. Sustainable harvesting techniques should be developed and quota established.

b) Controlled wood harvesting and alternative wood sources
It could be considered to designate certain blocks of mopane trees, where coppicing, a sustainable way of resource use, can be carried out. If fuelwood and wood for construction is needed village woodlots can be established (see Section 6.5 for the calculation of the annual increment of woody biomass in the planning zone).

5.5.2.2 Establishment of a veld product marketing channel

The formation of farmers' producer groups at local level could be considered. The installation of a veld product marketing board at District level could assist these local groups to sell their produce. Some further research by, and assistance from NGOs like Thusano Lefatseng and Veld Product Research in this matter could be stimulated.

5.6 Farmers' well being affected

5.6.1 Constraints

5.6.1.1 Water

Apart from water constraints for livestock use, the domestic water supply in settlements is a serious problem. In low rainfall years water is scarce and has to be fetched from far (Chanoga village or wellpoints in the Boteti River bed). This time consuming activity forms a heavy burden on arable and livestock production systems, that already suffer from a labour shortage.

5.6.1.2 Drought and decreasing income

Drought has a very negative impact on rural households' incomes. It does not only result in crop failures and loss of assets in the form of livestock, but it also severely limits other income earning options for farming households, particularly on-farm cash cropping, horticulture and the utilization of veld products. From the interviews with farmers it appeared, that drought conditions act as disincentive to investment in rainfed arable farming, because of the increased risk of crop failure.

5.6.2 Suggested options

5.6.2.1 Alleviating water shortages

Affordable and reliable water catchment (roof catchment) tanks erected in the lands areas could reduce water shortages for both domestic use and draught animals during the rainy season.

Boreholes developed under one of the government assistance schemes or water reticulation from Maun, Chanoga or from boreholes along the Boteti River, could alleviate water shortages for domestic and smallstock use in the settlements.

BOT/91/001
Field Document 12

Land Use Planning for Sustainable Agricultural Development

BOTSWANA

AGRICULTURAL LAND USE PLAN OF CHANOGA AGRICULTURAL EXTENSION AREA

Food & Agriculture
Organization of the
United Nations

Republic of
Botswana

United Nations
Development
Programme

OCTOBER 1996

5.6.2.2 Alternative income generating activities

In order to lower the dependence on drought sensitive crop and livestock production systems a diversification of farmers' activities should be pursued. Several small scale village based industries, partly based on agricultural production, can be introduced and promoted:

- blacksmithing (repair of implements, make donkey carts, tubs/buckets etc.)
- carpentry
- craft centre + training courses (production of baskets, ostrich egg shell necklaces and bracelets, decorated eggs, paintings, wood carvings, clay statues and pottery)
- creameries (sour milk, cream and cheese production)
- grain mill
- oil production plant from groundnuts or sunflower seeds
- rope making from sisal or *Sansevieria*
- tanneries (processing of hides and skins).

Assistance with the purchase of supplies and marketing of final products should be assured, when initiating one of the above activities. When electricity is needed, entrepreneurs should have the possibility to connect to the national grid, or otherwise alternative sources of energy should be explored, like solar power installations and windmills.

6. LAND EVALUATION

Land evaluation procedures have two focal points:

1. the land - to assess the suitability (profitability) of specific production systems for any selected land unit: optimization of the use of land, and

2. the farmer - to assess where (on which land unit) the present production system can be practiced with the best results and to indicate how to improve the present production system; optimization of the land use type.

Land suitability appraisals are normally made in terms of production, sustainability, the inputs needed to obtain that production and the financial or economic return (after FAO, 1993).

For the evaluation of rainfed crop and animal production systems on a quantitative basis, two computer simulation models have been used: CYSLAMB and APSRAMB, respectively. The evaluation of those production systems, for which no computer models are available, is done through qualitative suitability statements. The performance of selected production systems is evaluated on a financial basis, by means of gross margin analyses.

6.1 Evaluation of rainfed arable farming

Under the generally semi-arid conditions of Botswana, a large difference exists in performance of rainfed crop production systems between years due to the interannual variations in rainfall. Qualitative land evaluation, which assumes an average set of conditions, therefore has limited value, and the methods used in this chapter are of a quantitative nature.

Crop production systems have been simulated with the Crop Yield Simulation and Land Assessment Model for Botswana (CYSLAMB). This computer program, based on a year by year modelling, using historic rainfall data, evaluates the growth of five crops. Alternative annual crops are linked with CYSLAMB reference crops with similar physiological characteristics. Possible land improvements are mentioned, before conducting a financial analysis of the considered production systems.

6.1.1 CYSLAMB crops

6.1.1.1 Factors relevant for the use of CYSLAMB

<u>Introduction to the CYSLAMB program</u>

The CYSLAMB program models the performance of a selected crop under a predefined management system on a particular land unit (characterized by climate and soil type). The results of a simulation are given in quantitative terms, as dependable yields (in kg/ha), which are surpassed in at least 75% of the years. When comparing two yield figures generated by various management scenarios, a significance margin of 20% should be taken into account, when evaluating the effect of different management interventions.

For details on the scientific background and the operation of the program, reference is made to De Wit *et al.* (1993) and Radcliffe *et al.* (1994). Guidelines for the use of CYSLAMB are provided in Bekker *et al.* (1994).

<u>Choice of crop</u>

The CYSLAMB program is validated for five of the most commonly grown crops in Botswana: maize (var. *Kalahari Early Pearl*), sorghum (var. *Segaolane*), millet, cowpea and groundnut.

It should be noted, that yields simulated for the crop cowpea turn out low as compared to the yields of the other four crops under a similar management system. This could be related to the validation of the program for this crop. Trials conducted in the northwestern part of Ngamiland during the cropping season 1992/93, showed cowpea performances of 32-89% higher than CYSLAMB predictions (Mokhosoa and Bekker, 1993). So cowpea yields mentioned in this chapter should be interpreted with some caution.

Agro-ecologic parameters

Land units are typified for CYSLAMB by a combination of climatic and soil characteristics. The minimum dataset for the climate and soil parameters is listed in Table 21. As part of the climatic data, historic dekadal rainfall figures have been used. Care should be taken in selecting a range of years, as favoring years of above or below average rainfall, will significantly influence yield results (see Venema and Kgaswanyane, 1996).

Compilation of management systems

The minimum dataset of management parameters, is shown in Table 21.

Table 21. Minimum datasets for the use of CYSLAMB

CLIMATE	sunshine hours maximum temperature minimum temperature rainfall frequency potential evapotranspiration geographical latitude effective rainfall for the defined range of years
SOIL	textural class topsoil drainage class effective soil depth available water holding capacity
MANAGEMENT SYSTEM	capacity and frequency of irrigation applications weed infestation factor range of dekads and soil moisture requirements for early ploughing number of planting opportunities per season range of dekads used for planting rainfall and soil moisture requirements for planting time of weeding (days after planting)

Phenomena not taken into account by CYSLAMB

The outcome of CYSLAMB simulations can be considered as the potential yield achievable under the given management system, within the radiation, temperature, moisture and soil limitations of the evaluated land unit. Not modeled are adverse effects caused by climatic hazards (e.g. frost and hail), flooding, pests (including wildlife) and diseases, wind erosion and soil fertility degradation.

6.1.1.2 Pre-selection of land units through yield index calculation

In order to compare the potential for rainfed arable crop production in the Chanoga AEA with the national potential, a simulation was done of 5 production systems (5 crops), utilizing the same improved traditional management system (NLSM_N_1) for the 10 recognized land units. Based on the outcome of these simulations, a pre-selection of land units most suitable for rainfed cropping was made.

The management system NLSM_N_1, used for the National Land Suitability Map for Rainfed Crop Production (Radcliffe *et al.*, 1992) has the following characteristics:

Constant parameters

Irrigation capacity and frequency:	0mm, 0 times/dekad
Degree of weed infestation:	0% of maximum
Early ploughing period:	SEP3-NOV1
Soil moisture requirement for early ploughing:	30mm
Number of planting opportunities:	1
Planting period:	DEC1-FEB2
Soil moisture requirement for planting:	30mm
Effective rainfall requirement for planting:	30mm
Synoptic station:	Maun
Rainfall station:	Maun
Range of rainfall seasons:	1959-1989

Variable parameters

Plant density maize:	15,000 plants/ha
Plant density sorghum, millet, cowpea and groundnut:	50,000 plants/ha

Land units, typified by soil types (see Table 3 and Appendix I):

ALLUVIAL SYSTEM	
AS1: recent floodplain	CLplu, FLear, GLe, LPe, LVgcal, LVh
AS2: fossil floodplain - higher parts	ARheu, ARheu-ARl, ARl
AS3: fossil floodplain - depressions	CLhar, CLpar, CLplu, LVhar
AS4: fossil floodplain - pans	CLpluephycal
LACUSTRINE SYSTEM	
LS1: fossil lagoon - beach	ARheu
LS2: fossil lagoon - depressions	CLpar, CLplu, CLpluephycal, LVhar
LS3: fossil lagoon - pans	LPe
SANDVELD	
SV1: parabolic dune remnants	ARheu, ARheu-ARo
SV2: interdunal depressions	ARl, CLlsoar, CLpar, CLplu, LVhar
SV3: pans	CLl, CLlsoar

It is assumed that crops are rowplanted, no fertilizer is used and a weeding operation is conducted 30 days after planting.

The dependable yield estimates of the 5 crops combined for each land unit are translated into a non crop specific comparator, the Yield Index. The Yield Index allows a comparison between the dependable yield achieved in each land unit of the Chanoga AEA with the highest yields achieved in Botswana (Ymax), and is expressed on a scale from 0-1000. Through this parameter the performance for rainfed cropping of the land units of the study area can be placed in a national framework.

The calculation of the Yield Index is explained in Radcliffe *et al.* (1992). At a national level the Yield Index, based on dependable yields, was used for the separation of classes of dependable yield. Nine classes were distinguished; class A being the most suitable, class N not suitable. Table 22 shows the results of the simulations for the study area.

Table 22. **Dependable yield, Yield Index and yield classes for Chanoga AEA, simulated for the NLSM_N_1 management system**

LAND UNITS	DEPENDABLE YIELD (kg/ha)					YIELD INDEX	YIELD CLASS
	MAIZE	SORGHUM	MILLET	COWPEA	GROUNDNUT		
AS1	415	480	295	75	255	208	F
AS2	590	705	450	195	635	380	E
AS3	850	980	655	205	610	459	D
AS4	830	900	580	180	540	417	(D)*
LS1	560	670	420	190	620	366	E
LS2	910	1030	685	205	605	473	D
LS3	0	0	0	0	0	0	N
SV1	550	650	400	185	610	357	E
SV2	975	1110	740	220	650	507	D
SV3	920	1015	585	200	570	451	(D)*
Ymax	2070	2140	1560	430	1160		

* Although the two marked land units have a Yield Index to qualify for class D, due to a high chance of prolonged waterlogging during the rainy season, they are found not suitable for rainfed arable farming.

In relation to the nationwide potential, most land units have a suitability for rainfed cropping, that is moderately low (class D) to low (class E). One unit has a very low suitability (class F), while an other is entirely not suitable (class N). In terms of area, class D covers 34% of the AEA (26,954 ha), class E is found in 62% of the AEA (48,417 ha), class F in 2% (1590 ha) and class N occurs in 2% of the AEA (1334 ha). This picture is more refined and to an extend somewhat more pessimistic, than the National Land Suitability Map (Radcliffe *et al.*, 1992).

The most suitable land units (class D) are the depressions in the alluvial system (AS3, Yield Index 459), in the lacustrine system (LS2, Yield Index 473) and in the sandveld (SV2, Yield Index 507). The soils complex of these units is similar and characterized by medium textured soils, which are moderately well drained and have an available water holding capacity of 100-125mm/m and a moderate nutrient status.

Belonging to class E are all the higher land elements: the higher parts of the fossil floodplain (AS2, Yield Index 380), the beach of the fossil lagoon (LS1, Yield Index 366) and the parabolic dune remnants (SV1, Yield Index 357). Here the soils are sandy, well to somewhat excessively drained, with a low available water holding capacity and nutrient status.

The recent floodplain (AS1, Yield Index 208) classifies as class F, due to the poor to imperfect nature of the drainage of part of the soils. This limitation seems to be rather overemphasized. However, in years of abundant flow of the Boteti River, not much land in the floodplain is available for rainfed cropping. Molapo farming is conducted instead.

The land units AS4 and SV3 obtained a Yield Index high enough to classify as class D. However, due to the high risk of water stagnation during the growing season, the pans in the fossil floodplain (AS4) and on the sandveld (SV3) are found entirely unsuitable for rainfed crop production. Also class N are the pans in the fossil lagoon (LS3), due to the shallowness of the soils. Petrocalcic horizons in these last pans are restricting root penetration and hence make the soils unsuitable for crop growth.

It should be noted, that the suitability of the land units is based on an assessment of the individual soils found in the land units. The Yield Index of the complex, is calculated after the aggregation of the weighted dependable yields (see Appendix I for the weighting factors, which are based on the extent of each soil in a land unit). Not all soils in the complex of a land unit have the same potential for rainfed cropping. The best performing single soil units are Haplic Luvisols and Luvic Calcisols. The worst soils, not sustaining any crop growth are Areni-Eutric Fluvisol (drainage) and Eutric Leptosols (very shallow).

For each individual crop, yields under the simulated improved traditional management system NLSM_N_1 are on most land units 30-50% of the maximum yields achievable in the country (Ymax).

Based on the above and considering the location of the present concentrations of fields, the land units with a Yield Index > 350 and no flood risk are selected for further analysis. The following land units qualify: SV2, LS2, AS3, AS2, LS1 and SV1 (in descending order of Yield Index).

6.1.1.3 Improvement of present production systems on selected land units

In the previous section the emphasis has been on the performance of land units for a combination of the 5 CYSLAMB crops grown under one improved traditional management system. Here the emphasis will be on the farmer group and especially the way the present production systems can be improved.

Rotational management system compared to single farming household

As discussed in Section 4.4.3.1 two major production systems are practiced in the Chanoga AEA:

- mixed cropping in a rotational management system
- mixed cropping in a single farming household.

Mixed cropping can not be simulated with CYSLAMB, so a mono-cropping situation is assessed. The less resourceful farmer groups P1, P2 and W1 are mainly practicing the rotational system, while the more privileged groups W2 and R1 are often single farming households. The sixth group R2 are cattle rearers and is not interested in crop production, hence it is not included here.

A case study has been worked out to indicate the differences between both systems and to show the implications for the production of the individual households or family members.

The following assumptions have been made for the CYSLAMB simulations:

1. Ploughing/planting is carried out with draught animals, which are in good condition to use the first and second planting opportunity after December 21.
2. Each planting opportunity is triggered by a combination of rainfall and soil moisture content of both 20mm.
3. The maximum hectarage ploughed/planted per planting opportunity is 2-3 ha.
4. The crop sorghum (15,000 plants/ha) is grown on a Luvic Arenosol, using synoptic and rainfall data from the Maun station.
5. Traditionally, ploughing/planting is done on a semi-continuous basis from December 21 until March 10, here simulated by the use of a maximum of 4 planting opportunities.
6. 'Zero' yields due to not identified planting opportunities or crop failures have been taken into account for the calculation of dependable crop yields.

Table 23 depicts the results of the CYSLAMB simulations; dependable yield figures for each of the 4 planting opportunities individually and summary statistics for the situations in which more than one planting opportunity was used.

With help of the information given in Table 23, total production for a family and per family member has been calculated with as variable the number of hectares planted for each family member, see Table 24.

Table 23. Dependable yield figures case study rotational versus single household

	Yield individual planting opp's				Combined yield multiple planting opp's		
PLANTING OPPORTUNITY	1	2	3	4	1-2	1-3	1-4
DEPENDABLE YIELDS (kg/ha)	790	500	0	0	540	360	270

Table 24. Production per family and per individual family member

ROTATIONAL SYSTEM						
FAMILY MEMBERS	Hectare planted per family member					
	1	2	3	4	5	6
2	1 2x790 = 1580 790	2 4x540 = 2160 1080	2 6x540 = 3240 1620	3 8x360 = 2880 1440	4 10x270 = 2700 1350	4 12x270 = 3240 1620
3	1 3x790 = 2370 790	2 6x540 = 3240 1080	3 9x360 = 3240 1080	4 12x270 = 3240 1080		
4	2 4x450 = 2160 540	3 8x360 = 2880 720	4 12x270 = 3240 810			
SINGLE FARMING HOUSEHOLD						
1	1 1X790 = 790 790	1 2X790 = 1580 1580	1 3X790 = 2370 2370	2 4X540 = 2160 2160	2 5X540 = 2700 2700	2 6X540 = 3240 3240

EXPLANATION:

4 family members	2 4x450 = 2160 540	number of planting opportunities used total production (kg) per family (from 4 ha) total production (kg) per family member

Observations

* When a farmer is involved in the rotational management system with 1-3 other family members, more planting opportunities are required to plant the individual fields due to the rotation of labour force, draught power and implements, as compared to the situation of a single farming enterprise. The larger the group of family members is, the more planting opportunities are needed to complete planting of all individual fields. As a consequence planting continues until later in the season.
* Farmers engaged in the rotational system, should be recommended to plough and plant smaller areas, since the optimum total yield per family and per individual is obtained in a few planting opportunities. If a larger area is planted, the risk of crop failure increases and hence the total yield per hectare planted decreases. The extra effort spent on ploughing/planting is most likely a waste of resources and energy. The optimal areas planted are:
  - 2 family members: plant 3 hectares each in 2 planting opportunities
  - 3 family members: plant 2 hectares each in 2 planting opportunities
  - 4 family members: plant 2 hectares each in 3 planting opportunities
* When a farmer is totally independent in his/her management operations (single farming household), he/she is recommended to plant 3 hectares during the first and another 3 hectares (if feasible) during the second planting opportunity, in order to obtain an optimum production.

The main conclusion is, that single farming households (when enough labour available) are in a better position to achieve a high production, than farmers depending on a rotation of implements and labour. It should be promoted to supply all individual family members having enough labour with the necessary implements to conduct crop production individually.

The next section deals with different scenarios to improve the single farming situation.

Evaluation of single farming situation

In this section the suitability for rainfed cropping of the 6 pre-selected land units is evaluated with the help of CYSLAMB with as aims:

- to simulate the present yield figures (baseline scenarios)
- to establish the scope for improvement based on advanced management interventions (improved scenarios)
- to assess the optimal crop management system (optimal scenario) for each land unit, in terms of yield and gross margin.

The constant parameters have been set as follows:

No irrigation gift is simulated, the weed infestation factor is kept at 80% and no early ploughing is conducted. The late planting farmers, normally come into action after a rainfall event of at least 30mm. The more motivated farmers, who plant early, do that after a shower of at least 20mm. Maun is taken as synoptic and rainfall station. The range of historic rainfall seasons is chosen from 1974-1993. The last season of this range corresponds with the year the socio-economic and financial data for this study were collected. The chosen 20 year period seems to reflect an array of wet and dry seasons, approaching best the cyclical trend in the rainfall pattern of Botswana. The first weeding operation is set throughout at 30 days after planting.

As the individual farmers are spread over the AEA, and no group is bound to a particular land unit, all scenarios are run for the six selected land units.

BASELINE SCENARIOS

Most farming households are engaged in traditional low input crop production systems. The following 4 baseline management scenarios represent this situation. The management parameters simulated are presented in Table 25.

Table 25. Baseline management scenarios for CYSLAMB simulations

CODE	PLANTING PERIOD (dekad)	RAINFALL AND SOIL MOISTURE (mm)	PLANTING OPPORTUNITIES	TARGET PLANT DENSITY (plants/ha)
Bs1	DEC3 - MAR1	30	4	15,000
Bs2	NOV3 - MAR1	20	4	15,000
Bs3	DEC3 - MAR1	30	3	15,000
Bs4	NOV3 - FEB1	20	3	15,000

Management system Bs1: The households following this scenario plant late (from DEC3), usually after a rainfall event of 30mm. Due to labour and draught power constraints planting is done late and in order to finish the entire field 4 planting operations are used.

Management system Bs2: This management system is practiced by more motivated farmers; they take the risk to plant early, after a shower of 20mm (from NOV3). They still have some draught power and/or labour problems and use 4 planting opportunities to finish their entire field.

Management system Bs3: Households practicing this scenario plant late (from DEC3, normally after a shower of 30mm) like management system Bs1, but utilize 3 planting opportunities. No labour shortages occur in these households.

Management system Bs4: Farmers carrying out this management system are more motivated, than those following management system Bs3, manage to plant early (from NOV3, usually after a rainfall event of 20mm) and are using 3 planting opportunities.

The management systems Bs1 and Bs2 are common amongst farmers from the groups P1, P2 and W1. Bs3 and Bs4 are mainly practiced by farmers belonging to the groups W2 and R1. The vast majority of farmers uses donkeys as draught power, hence the large number of planting opportunities used to plough the entire field. No farmer uses chemical fertilizer, nor kraal manure.

The yields achieved on the pre-selected land units for the 5 CYSLAMB crops under the baseline scenarios are show in Table 26. It should be noted, that the yields of these baseline scenarios have been decreased by 20%, in order to simulate the loss of produce due to pests and diseases, caused by a lack of plant protection measures. The initial CYSLAMB yields for groundnut are based on pods. In conformity with Paris *et al.* (1995) a yield reduction factor due to shelling of 33% has been applied (so from the unshelled CYSLAMB produce, 67% remains as shelled groundnuts).

Table 26. CYSLAMB yield results (kg/ha) for baseline management scenarios

MAN. SYS.	LAND UNIT	MAIZE	SORGHUM	MILLET	COWPEA	GROUNDNUT
Bs1	SV2	17	121	58	29	90
	LS2	10	113	54	27	85
	AS3	9	110	53	26	85
	AS2	0	90	42	18	72
	LS1	0	88	40	16	70
	SV1	0	86	38	16	69
Bs2	SV2	98	275	182	89	228
	LS2	88	254	169	84	221
	AS3	88	251	168	84	218
	AS2	59	206	141	67	196
	LS1	56	200	136	64	193
	SV1	54	196	132	64	190
Bs3	SV2	22	161	78	37	120
	LS2	17	150	74	35	114
	AS3	15	148	72	34	113
	AS2	0	123	58	26	99
	LS1	0	120	56	24	96
	SV1	0	118	54	24	95
Bs4	SV2	133	351	238	110	258
	LS2	118	328	220	105	244
	AS3	118	326	218	103	248
	AS2	77	272	174	90	241
	LS1	72	264	168	88	236
	SV1	70	259	163	86	233

Observations

* When resources are available and 3 planting opportunities are used instead of 4, yields are slightly higher (scenarios Bs3 and Bs4 compared to Bs1 and Bs2, respectively).
* Early planting (from NOV3 after a rainfall event of 20mm), whether utilizing 3 or 4 planting opportunities (scenarios Bs2 and Bs4) leads to considerably higher yields than planting late (from DEC3 after a rainfall event of 30mm, scenarios Bs1 and Bs3).
* From the farmers' point of view the simulations prove, that all crops are best grown on the land unit SV2, LS2 and AS3.
* Seen from the factor land in terms of yield, sorghum is the best performing crop on all land units under all management systems. Maize performs very poorly, when planted (too) late and mediocre when planted early. Groundnut and millet do moderately well on most land units.

INTERMEDIATE SCENARIOS

Improvements to the baseline scenarios can be simulated by several interventions in the management system. It is assumed, that intermediate scenarios go hand in hand with improved crop husbandry practices and small to medium investments. Before farmers can carry out one of the simulated intermediate scenarios, it is imperative, that labour and implements form no limitation to carry out timely operations.

The improved interventions simulated here, concern a reduction of the number of planting opportunities (more labour and implements available or a smaller hectarage planted) and the use of fertilizer, see Table 27 for the characteristics of the intermediate management systems run. The weeding dates are set at 30 days after planting and the target plant density at 15,000 plants/ha for all intermediate scenarios.

Table 27. Intermediate management scenarios for CYSLAMB simulations

CODE	PLANTING PERIOD (dekad)	RAINFALL AND SOIL MOISTURE (mm)	PLANTING OPPORTUNITIES	FERTILIZER (increased P level)
Im1	DEC3 - MAR1	30	2	none, 6 ppm, 10 ppm
Im2	DEC3 - MAR1	30	1	none, 6 ppm, 10 ppm
Im3	NOV3 - FEB1	20	2	none, 6 ppm, 10 ppm

The yields achieved on the pre-selected land units for the 5 CYSLAMB crops under the intermediate scenarios are shown in Table 28. No correction for yield losses due to pests and diseases has been applied for the intermediate scenarios, as it is assumed that appropriate plant protection measures are taken. To simulate this, the production costs will include a fixed amount for one spraying operation with alphametrin. As for the baseline scenarios, the groundnut yields are given for shelled produce (shelling reduction factor of 33%).

Table 28. CYSLAMB yield results (kg/ha) for intermediate management scenarios

MAN. SYS.	LAND UNIT	MAIZE fertilizer (ppm P)			SORGHUM fertilizer (ppm P)			MILLET fertilizer (ppm P)			COWPEA fertilizer (ppm P)			GROUNDNUT fertilizer (ppm P)		
		0	6	10	0	6	10	0	6	10	0	6	10	0	6	10
Im1	SV2	41	70	91	305	352	428	145	180	220	66	80	80	226	255	295
	LS2	29	64	85	284	345	419	137	180	220	64	78	80	213	250	290
	AS3	26	64	85	278	346	420	132	180	220	62	80	80	212	253	293
	AS2	0	30	60	226	340	410	104	180	220	52	80	80	180	249	289
	LS1	0	30	60	220	340	410	100	180	220	50	80	80	174	248	288
	SV1	0	30	60	215	340	410	97	180	220	48	80	80	172	248	288
Im2	SV2	89	131	191	485	564	674	287	351	432	128	150	170	387	437	504
	LS2	63	119	179	453	558	668	268	350	430	123	148	168	369	431	498
	AS3	56	120	180	438	557	667	259	350	430	120	150	170	367	442	509
	AS2	0	60	120	326	518	636	206	350	430	102	150	170	328	456	523
	LS1	0	60	120	310	510	630	200	350	430	100	150	170	322	456	523
	SV1	0	60	120	304	510	630	194	350	430	98	150	170	316	456	523
Im3	SV2	252	292	369	519	608	719	353	423	520	165	179	211	389	442	510
	LS2	222	277	348	489	601	713	324	415	509	157	177	209	369	434	502
	AS3	220	289	361	478	608	719	323	427	521	153	179	214	372	449	517
	AS2	148	244	306	392	610	720	276	440	538	132	180	220	340	469	543
	LS1	140	240	300	380	610	720	270	440	540	130	180	220	335	469	543
	SV1	134	240	300	372	610	720	262	440	540	128	180	220	328	469	543

Observations

* The following five observations benefit the farmers' management decisions. The yields achieved under management system Im1_0 (late planting in 2 opportunities, no fertilizer) are higher than those reached with the late planting baseline scenarios using 3 or 4 planting opportunities (Bs1 and Bs3).
* For maize, millet and cowpea late planting using 2 planting opportunities without fertilizer (scenario Im1_0) leads to lower yields, than early planting utilizing 3 or 4 opportunities (scenarios Bs2 and Bs4). Sorghum and groundnut under scenario Im1_0 yield equal to scenario Bs2 and lower than scenario Bs4.
* For all crops but maize, late planting using 1 planting opportunity and no fertilizer (scenario Im2_0) achieves similar or better yields than early planting utilizing 3 or 4 opportunities (scenarios Bs2 and Bs4). The yield predictions for late planted maize under scenario Im2_0 are significantly lower than for the early planted baseline scenarios Bs2 and Bs4. In other words, if maize is not planted before DEC3 without fertilizer, it is better not planted at all. If phosphorus levels are raised upto 10 ppm, a higher yield than early planted maize in 3 or 4 opportunities (scenarios Bs2 and Bs4) can be expected on all land units.
* The intermediate management systems based on early planting using 2 plant occasions and no fertilizer (scenarios Im3_0) show higher yields for maize, millet and cowpea, than the late planted intermediate scenarios (Im1_0 and Im2_0) on all 6 selected land units. The yields of sorghum and groundnut are equal to Im2_0 yields (not significantly higher) and higher than Im1_0.
* The use of fertilizer, an application that brings the soil's phosphorus level upto 6 ppm, does significantly increase the yields as compared to the zero fertilizer gift for all crops under all three management scenarios and on all land units. A fertilizer gift upto 10 ppm phosphorus, significantly increases maize, sorghum and millet yields (as compared to the application upto 6 ppm) for all intermediate management systems and on all land units. Sorghum grown under management system Im3 on any land unit, forms an exception and performs only slightly better. For cowpea and groundnut the increased fertilizer application does not lead to significantly higher yields for all three intermediate scenarios and on all land units. Where significant, the increase in yield due to an increased fertilizer application is highest under the Im3 management scenario.
* When looking at the optimization of the use of the land, it could be noted that sorghum is the highest yielding crop on all land units under all intermediate scenarios. Groundnut and millet reach moderately high yields, while cowpea and maize show the lowest figures. And as accounts for the farmers' decisions, the more advanced the management interventions undertaken, the higher the yields on each land unit.

OPTIMAL SCENARIOS

The optimal management systems assume a high standard of crop husbandry and medium to high investments. The interventions simulated are summarized in Table 29. Like for the intermediate scenarios, the weeding dates are set at 30 days after planting and the target plant density at 15,000 plants/ha.

Table 29. Optimal management scenarios for CYSLAMB simulations

CODE	PLANTING PERIOD (dekad)	RAINFALL AND SOIL MOISTURE (mm)	PLANTING OPPORTUNITIES	FERTILIZER (increased P level)
Op1	NOV3 - FEB1	20	1	none, 6 ppm, 10 ppm

The yields for the 5 CYSLAMB crops for the pre-selected land units are shown in Table 30.

Table 30. CYSLAMB yield results (kg/ha) for optimal management scenarios

MAN. SYS.	LAND UNIT	MAIZE fertilizer (ppm P)			SORGHUM fertilizer (ppm P)			MILLET fertilizer (ppm P)			COWPEA fertilizer (ppm P)			GROUNDNUT fertilizer (ppm P)		
		0	6	10	0	6	10	0	6	10	0	6	10	0	6	10
Op1	SV2	502	593	732	691	795	945	530	624	747	198	223	256	450	510	590
	LS2	443	562	695	648	783	933	489	606	727	189	222	255	427	503	582
	AS3	439	582	720	640	795	945	484	616	745	194	225	261	421	508	588
	AS2	286	498	620	498	754	896	366	566	684	164	222	262	370	511	591
	LS1	270	490	610	480	750	890	350	560	680	160	220	260	362	509	590
	SV1	260	490	610	470	750	890	340	560	680	157	220	260	355	509	590

Observations

* When farmers are looking for optimizing their production systems, one of the optimal scenarios can be recommended. The optimal scenarios yield at least 75% higher than the baseline scenarios, for all 5 crops on all 6 land units, demonstrating the range of opportunities to improve rainfed crop production.
* For all crops but groundnut, the optimal scenarios Op1 (early planting using 1 planting opportunity, with and without fertilizer) perform better than the intermediate scenarios of early planting and 2 planting opportunities Im3. The groundnut yields achieved under the management systems Op1 yield higher than the Im3 scenarios, but the difference is not significant. In other words, planting of groundnut can be spread over 2 planting opportunities.
* Under the optimal scenario without fertilizer Op1_0, all crops achieve the highest yields on land unit SV2. When simulating fertilizer applications (scenarios Op1_6 and Op1_10), the grain crops obtain maximum yields on the land unit SV2, while the legume yields do not significantly differ for all six land units.
* From the point of view of optimizing the use of the land, it can be noted, that sorghum produces the most on all land units under the optimal management scenarios. Maize, millet and groundnut reach intermediate yields, while cowpea seems to yield the lowest on all 6 selected land units.

CYSLAMB simulations carried out to verify the effect of various plant densities and weeding dates have shown no significantly different yield figures.

The above section has shown management interventions, leading to improved crop yields. In Section 6.1.4 a gross margin analysis is conducted, in order to screen the scenarios on their financial viability. In Chapter 7 a toolkit with options for improvement will be presented, indicating which options are recommendable and achievable for each farmer group.

6.1.2 Alternative crops

Apart from the evaluated grain crops and legumes used for staple diet, a number of alternative crops is suitable for growing under the climatic and soil conditions prevailing in the Chanoga AEA. The choice of alternative crops is based on the database ECOCROP 1 (FAO, 1994), Edwards *et al.* (1989), LUPSAD (1995), Saunders (1992), Sims (1981), Taylor & Moss (1983) and TNMAF (1989). The crops are listed in 2 categories: cash crops and fodder crops (see Table 31).

For the alternative annual crops a yield estimate is given, making use of a "CYSLAMB reference crop" with similar growth requirements. The alternative crop yields are linked with the estimated yield of the CYSLAMB reference crop, grown under the improved scenario Im3_6 (with fertilizer upto 6 ppm P), carrying out improved crop husbandry practices. The yield classes of the alternative crops have been derived from known optimal yields, through a comparison table as presented in LUPSAD (1995). The yields for the alternative perennial crops are only indicative and are based on optimal yields found in literature, and consequently down graded to approach Botswana conditions.

Table 31. Alternative crops

MAIN USE	CROP	CYSLAMB * REFERENCE CROP	YIELD ** (kg/ha)	PRODUCE	OTHER USES	REMARKS
CASH CROPS	Cluster bean (*Cyamopsis tetragonoloba*)	Millet	170-290	pulses	fodder (hay 1.1-1.9 t/ha), green manure	drought resistant
	Devil's claw / Sengaparile (*Harpagophytum procumbens*		500-1000	tubers	tea, medicines	drought resistant, very low input crop
	Hibiscus (*Hibiscus cannabinus*)		250-350	dried flower	fibre (750-850 kg/ha), fodder	used for tea, hedge rows
	Jugobean (*Vigna subterranea*)	Millet	150-250	pulses		drought resistant
	Pigeon pea (*Cajanus cajan*)	Sorghum	130-200	pulses	fodder, pods, green manure	annual or short-lived perennial, hedge rows
	Prickly pear (spineless variety)		1800-2200	fruit	fodder (leaves 80-90 t/ha)	perennial (min. 12 years), produce from year 2, hedge rows
	Sesame (*Sesamum indicum*)	Sorghum	90-130	pulses		
	Sisal (*Agave sisalana*)		450-750	dried fibre		produce from year 2-12
	Sunflower (*Helianthus annuus*)	Sorghum	170-260	seed		drought resistant
FODDER CROPS	Buffel grass (*Cenchrus ciliaris*)	Millet	1750-2500	hay		perennial, very drought resistant
	Lablab bean (*Dolichos lablab*)	Sorghum	800-1200	hay	green manure, pulses	
	Moth bean (*Phaseolus aconitifolius*)	Cowpea	2000-2400	green forage	green manure, pods, pulses (600-720 kg/ha)	
	Siratro (*Macroptilium atropurpureum*)	Maize	1500-1950	hay		perennial

* Only for annual crops.

** Yields are based on intermediate management system lm3_6 (fertilizer upto 6 ppm P), where a reference crop is used or on literature otherwise, and are valid for all land units.

6.1.3 Mitigation of additional limiting factors

The above sections assumed crop production is conducted under ideal circumstances. However, on a yearly basis pest and disease control measures may have to be taken, while for a long term sustainable production wind erosion control and soil fertility maintenance should be carried out.

Pest and disease control

Bird scaring operations, where needed, are normally conducted by family members, which form part of the farm labour force. Pest and disease control, like spraying operations against army worm, boll worm, corn crickets or aphids are usually organized through the AD and carried out by the Plant Protection Division of MoA. As such, these interventions do not occur on the farm budget. Cost/ha for a spraying operation with an insecticide or fungicide are estimated at P 20 (Kristensen and Molelo, 1996) and should be included in the gross margin analysis, when born by the farmer.

Wind erosion control

Two designs for agroforestry based protection of arable fields are discussed in Section 6.3.2. The first system is based on a combination of hedge rows with tree wind breaks, where the second system combines tree wind breaks with life perimeter fencing. The proposals include selection lists of suitable tree and shrub species, layouts and cost estimates.

Soil fertility maintenance

In order to assure the predicted crop production figures, the nutrients removed from the soil through harvesting should be replenished. Several management intervention that only cost farm labour are ploughing back in the soil of crop residues, instead of being grazed off by livestock, proper crop rotation of grain crops and legumes, and the application of kraal manure, green manure (from agroforestry systems) or mulching. To compensate soil nutrient loss with inorganic fertilizer, approximately 22 kg single superphosphate/ha is required per 1000 kg/ha maize grain yield. This corresponds with the extraction of 2.3 kg of P from the soil. At 1994/95 BAMB price level, a maintenance dose of single superphosphate fertilizer would cost P 12.50/ha (LUPSAD, 1995).

The costs involved in the mitigation of these additional limitations can be included in the gross margin, where it involves minor land improvement (pesticides and fertilizer) and should be calculated in a separate financial analysis, where it concerns major land improvements like wind erosion control measures.

6.1.4 Financial analysis

6.1.4.1 Gross margin analyses of CYSLAMB crops

The financial viability of the different production systems simulated with the CYSLAMB program in Section 6.1.1.3 was evaluated by means of gross margin analyses. The costs of production and the value of produce are mainly based on BAMB prices of the cropping season 1994/95, and are listed in Section 4.4.5 (for cowpea the value of the most profitable variety, i.e. *Black Eye*, has been taken).

Gross margin analyses do not consider fixed costs, nor farm labour. This means that the costs of land preparations, ploughing/planting, weeding, bird scaring, harvesting and threshing of grain or shelling of beans and groundnuts are excluded from the calculations. Variable costs for seeds, spraying and fertilizer are taken into account.

The yields achieved by the baseline scenarios have been reduced by 20%, in order to simulate the negative effect of pests and diseases. This decreased the value of the produce concurrently. For the intermediate and optimal scenarios a flat rate of P 20/ha is included in the gross margin analysis, simulating an effective spraying operation with the pesticide Alphametrin. De Wit (1992) describes a residual effect of a single superphosphate fertilizer application of three years. The gross margin analysis of the management systems involving a fertilizer application, simulates this residual effect by taken into account a third of the actual fertilizer cost. The gross margin of all optimal scenarios comprises P 12.50 as cost of a maintenance dose of SSP fertilizer.

The presented gross margins do not include any drought relief subsidies. If the full package of ploughing subsidy (Pula 120/ha), rowplanting subsidy (Pula 50/ha) and free maize, sorghum or millet seeds (1994/95) is taken into consideration, all figures will look much more positive.

When interpreting the gross margins, it should be born in mind, that the figures are based on potential dependable CYSLAMB yields. When comparing the performance of different management and production systems, the gross margins provide a relative measure of success and like the yields a significance margin of 20% should be considered.

To facilitate the interpretation of the Tables 32, 33 and 34 with gross margin figures, the following key can be used:

51.57 most profitable land unit for a given production system

104.69 most profitable combination of land unit and management system for a specific crop

260.12 most profitable production system for a given land unit

BASELINE SCENARIOS

The results of the gross margin analysis of the baseline scenarios are shown in Table 32.

Table 32. Gross margins (Pula/ha) of baseline scenarios

MAN. SYS.	LAND UNIT	MAIZE	SORGHUM	MILLET	COWPEA	GROUNDNUT
Bs1	SV2	4.78	51.57	22.97	19.00	87.08
	LS2	1.43	47.94	21.16	17.30	81.93
	AS3	0.95	46.58	20.70	16.45	81.93
	AS2	−3.36	37.50	15.71	9.66	68.54
	LS1	−3.36	36.59	14.80	7.96	66.48
	SV1	−3.36	35.68	13.89	7.96	65.45
Bs2	SV2	43.58	121.49	79.27	69.94	229.22
	LS2	38.79	111.96	73.37	65.70	222.01
	AS3	38.79	110.59	72.91	65.70	218.92
	AS2	24.90	90.16	60.65	51.26	196.26
	LS1	23.46	87.44	58.38	48.72	193.17
	SV1	22.51	85.62	56.57	48.72	190.08
Bs3	SV2	7.18	69.73	32.05	25.79	117.98
	LS2	4.78	64.74	30.24	24.10	111.80
	AS3	3.83	63.83	29.33	23.25	110.77
	AS2	−3.36	52.48	22.97	16.45	96.35
	LS1	−3.36	51.12	22.06	14.76	93.26
	SV1	−3.36	50.21	21.16	14.76	92.23
Bs4	SV2	60.35	155.99	104.69	87.77	260.12
	LS2	53.16	145.55	96.52	83.53	245.70
	AS3	53.16	144.64	95.61	81.83	249.82
	AS2	33.52	120.13	75.64	70.79	242.61
	LS1	31.13	116.50	72.91	69.09	237.46
	SV1	30.17	114.23	70.64	67.39	234.37

Observations

* From the farmers point of view, the most profitable land unit for all production systems (combination of management system and crop) is SV2, the interdunal depressions. The gross margins of SV2, however, do not significantly differ from those of the land units LS2 and AS3. In most cases a significant difference in gross margin exists between production systems carried out on land unit SV2 and those on the land units AS2, LS1 and SV1. The groundnut gross margins for all land units under each of the production systems Bs2, Bs3 and Bs4, on the contrary, are all within a 20% range.
* For the farmers' interest, the management system Bs4 (early planting using 3 opportunities) turns out to be most profitable for the crops maize, sorghum, millet and cowpea on all land units, as compared to the other three baseline scenarios. For the 4 mentioned crops land unit SV2 is the best option, although no significant difference exist with the land units LS2 and AS3. A large difference does, however, occur with the land units AS2, LS1 and SV1. The groundnut gross margins are highest (but not significantly) for the land units SV2, LS2 and AS3 under management system Bs4 as compared to Bs2. For the more sandy land units AS2, LS1 and SV1, the significantly highest gross margins are reached under management system Bs4.
* Seen from the point of view land, on all land units, the highest returns can be expected from the growing of groundnut under management system Bs4. The second most profitable production system for all land units is groundnut under management system Bs2, followed by sorghum under management system Bs4 as third. Maize is in all cases the least profitable crop.

INTERMEDIATE SCENARIOS

The results of the gross margin analysis of the intermediate scenarios are shown in Table 33.

Observations

It should be noted, that in the following observations generally a significant difference exists between the performance of production systems in the depressions (land units SV2, LS2 and AS3, which are situated on the slightly heavier soils) and production systems carried out on the higher parts of the landscape (land units AS2, LS1 and SV1, characterized by sandy soils). Within the two groups of land units no significant difference is found.

* From the farmers' point of view the most profitable land unit for the crops sorghum, millet, cowpea and groundnut grown under management system Im1 is SV2, the interdunal depressions. Maize grown under the Im1 scenario turns into a loss on all land units.
* SV2 is the most profitable land unit for maize, sorghum, millet, cowpea and groundnut without fertilizer, grown under the management systems Im2 and Im3. Groundnut with fertilizer is best grown on the land unit AS2.
* For maize, sorghum, millet and cowpea the most profitable combination of land unit and management system under the intermediate scenarios is SV2 and Im3_10. Groundnut reaches the highest gross margin under management system Im3_10 on land unit AS2.
* In accordance with the yield results, the gross margins of the Im1_0 scenarios for all crops but maize, are generally significantly higher than the gross margins of the baseline scenarios Bs1 and Bs3.
* The application of fertilizer to all crops under the scenarios Im1_6 and Im1_10 does not render a significant profit on the land units SV2, LS2 and AS3. The initial phosphorus content of their soils is moderate and fertilizer does not raise the yields, nor the gross margins considerably. On the sandier land units (with a lower initial phosphorus status) a fertilizer gift upto 6 ppm P (scenario Im1_6) does result in a significantly higher gross margin for the crops sorghum, millet and groundnut. A fertilizer increase upto 10 ppm P proves to be not profitable (yield increase too small to pay of the extra fertilizer), on the sandy land units under scenario Im1.
* Scenario Im1_0 shows no improvement for any crop on any of the land units, as compared to the baseline scenarios Bs2 and Bs4. Early planting using 3 or 4 planting opportunities pays off

Table 33. Gross margins (Pula/ha) of intermediate scenarios

MAN. SYS.	LAND UNIT	MAIZE fertilizer (ppm P)			SORGHUM fertilizer (ppm P)			MILLET fertilizer (ppm P)			COWPEA fertilizer (ppm P)			GROUNDNUT fertilizer (ppm P)		
		0	6	10	0	6	10	0	6	10	0	6	10	0	6	10
Im1	SV2	-3.72	-1.61	-18.23	115.11	124.66	132.50	42.47	46.58	38.06	32.67	32.78	6.10	209.42	227.51	242.03
	LS2	-9.47	-7.12	-23.77	105.58	118.86	125.74	38.84	43.95	35.40	30.98	28.45	3.44	196.03	219.73	234.22
	AS3	-10.91	-8.75	-25.29	102.85	117.67	124.67	36.57	42.31	33.87	29.28	28.51	1.91	195.00	221.18	235.78
	AS2	-23.36	-34.31	-46.59	79.24	105.68	110.81	23.86	33.04	24.55	20.79	19.24	-7.41	162.04	207.79	222.34
	LS1	-23.36	-35.64	-47.93	76.52	104.35	109.47	22.04	31.71	23.21	19.09	17.91	-8.75	155.86	205.43	219.97
	SV1	-23.36	-35.64	-47.93	74.25	104.35	109.47	20.68	31.71	23.21	17.39	17.91	-8.75	153.80	205.43	219.97
Im2	SV2	19.27	27.60	29.67	196.83	220.91	244.18	106.94	124.21	134.31	85.31	92.21	82.51	375.25	414.97	457.30
	LS2	6.82	19.23	21.26	182.30	215.56	238.79	98.31	121.13	130.74	81.07	87.88	78.15	356.71	406.16	448.46
	AS3	3.46	18.07	20.21	175.49	213.47	236.81	94.23	119.49	129.21	78.52	87.94	78.32	354.65	415.85	458.26
	AS2	-23.36	-19.94	-17.85	124.64	186.49	213.41	70.16	110.22	119.89	63.24	78.67	69.00	314.48	421.00	463.36
	LS1	-23.36	-21.27	-19.19	117.38	181.53	209.35	67.44	108.89	118.55	61.54	77.34	67.66	308.30	419.67	462.02
	SV1	-23.36	-21.27	-19.19	114.66	181.53	209.35	64.72	108.89	118.55	59.84	77.34	67.66	302.12	419.67	462.02
Im3	SV2	97.35	104.72	114.93	212.27	240.89	264.61	136.90	156.90	174.26	116.73	116.83	117.32	377.31	420.12	463.48
	LS2	82.98	94.91	102.21	198.65	235.08	259.22	123.74	150.64	166.60	109.93	112.50	112.96	356.71	409.25	452.58
	AS3	82.02	99.02	106.91	193.65	236.62	260.42	123.28	154.45	170.53	106.54	112.56	115.68	359.80	423.06	466.50
	AS2	47.53	68.20	71.24	154.61	228.26	251.55	101.94	151.08	168.92	88.71	104.14	111.45	326.84	434.39	483.96
	LS1	43.70	64.95	67.03	149.16	226.93	250.21	99.22	149.75	168.49	87.01	102.81	110.11	321.69	433.06	482.62
	SV1	40.83	64.95	67.03	145.53	226.93	250.21	95.59	149.75	168.49	85.31	102.81	110.11	314.48	433.06	482.62

Table 34. Gross margins (Pula/ha) of optimal scenarios

MAN. SYS.	LAND UNIT	MAIZE fertilizer (ppm P)			SORGHUM fertilizer (ppm P)			MILLET fertilizer (ppm P)			COWPEA fertilizer (ppm P)			GROUNDNUT fertilizer (ppm P)		
		0	6	10	0	6	10	0	6	10	0	6	10	0	6	10
Op1	SV2	204.60	236.40	276.31	277.85	313.29	354.71	204.76	235.65	264.82	132.24	141.68	143.03	427.64	477.66	533.38
	LS2	176.34	218.93	255.92	258.33	305.21	346.60	186.15	224.85	253.08	124.60	138.21	139.51	403.95	467.82	522.48
	AS3	174.42	226.87	266.37	254.70	309.02	350.52	183.88	227.75	259.72	128.85	139.12	143.08	397.77	471.33	527.13
	AS2	101.13	177.36	209.15	190.23	281.14	318.95	130.30	195.78	222.70	103.38	127.30	134.60	345.24	465.15	520.90
	LS1	93.47	172.20	203.02	182.06	277.99	314.89	123.04	191.73	219.55	99.98	124.27	131.57	337.00	461.76	518.53
	SV1	88.68	172.20	203.02	177.52	277.99	314.89	118.50	191.73	219.55	97.43	124.27	131.57	329.79	461.76	518.53

compared to late planting in 2 occasions. When fertilizer is applied (scenarios Im1_6 and Im1_10), the gross margins are lower than or equal to the gross margins of the Bs2 and Bs4 scenarios. This is indicating, that late planting with fertilizer, using more than 1 planting opportunity does not pay off as compared to early planting without fertilizer using multiple planting occasions.

* For all crops but maize, scenario Im2_0 (late planting using 1 opportunity) is more profitable than Bs2 (early planting using 4 opportunities) on all land units. Only sorghum grown under scenario Im2_0 on the depressions and groundnut on all land units, turn out more profitable than the scenario Bs4. When comparing the management systems Im2_6 and Im2_10 with the baseline scenario Bs4, it can be concluded that the use of fertilizer is not worthwhile for the crops maize and cowpea on all land units. The crops sorghum, millet and groundnut, however, achieve significantly higher gross margins under these circumstances. This indicates, that for these three crops late planting in one go with the use of fertilizer is more profitable, than early planting in 3 opportunities without the use of fertilizer.
* All Im3 production systems are more profitable than the corresponding Bs4 scenarios.
* All Im3 scenarios for maize, millet and cowpea show significantly higher gross margins on all land units than the Im2 management systems. For sorghum the differences are only significant for the sandier land units, while for groundnut no difference exists on any land unit.
* Maize grown under the management systems Im2 achieves modest gross margins on the land units SV2, LS2 and AS3, but is not profitable on the sandier land units. The application of fertilizer upto 6 ppm P on the heavier soils, does significantly increase the gross margins, but an increase to 10 ppm P is not financially interesting. For sorghum, millet and groundnut under Im2, it is significantly more profitable to apply upto 10 ppm P than upto 6 ppm P in the depressions. On the sandier land units a fertilizer gift upto 6 ppm P seems to pay off better. In the case of growing cowpea under Im2 management, it is better not to apply any fertilizer on the heavier soils and upto 6 ppm P on the sands.
* Under the Im3 scenarios, it is significantly more profitable to apply upto 10 ppm P for maize, sorghum, millet and groundnut on the land units SV2, LS2 and AS3. On the other land units a fertilizer gift upto 6 ppm P is significantly more profitable. Regarding cowpeas, it is recommendable not to fertilize on the land units SV2, LS2 and AS3, and to apply upto 10 ppm P on the other land units.
* Seen from the point of view of the land, the highest gross margins are reached on all land units by the growing of groundnut under the management system Im3_10. However, no significant difference does occur on any land unit between the growing of groundnut under Im3_10, Im3_6, Im2_10 and Im2_6. This means, that fertilized late planted groundnut using 1 planting opportunity, performs as well as fertilized early planted groundnut in 2 occasions. The second most profitable production system on all land units, is growing sorghum under the management scenarios Im2 and Im3 (with or without fertilizer), followed by millet under scenario Im3. Cowpea and maize, both with management system Im3, generate the lowest gross margins.

OPTIMAL SCENARIOS

The results of the gross margin analysis of the optimal scenarios are shown in Table 34.

Observations

* For all optimal production systems, land unit SV2 shows the highest gross margins.
* All crops are most profitably grown under management system Op1_10 on land unit SV2.
* The Op1 scenarios appear to be more profitable than the most advanced baseline scenario for all crops on all land units. The scope for improvement in gross margin varied from 85-620% for maize, for sorghum from 85-190%, for millet from 85-225%, for cowpea from 40-115% and for groundnut from 45-130%, depending on the land unit and the amount of fertilizer used.
* For maize, sorghum and cowpea, all Op1 scenarios on all land units turn out significantly more profitable than the intermediate scenarios. For millet and groundnut on all land units, the gross margins for the optimal scenarios are higher, but not significantly than the gross margins of the Im2 and Im3 scenarios.

* For all crops on all land units, the gross margins achieved under Op1_10 are not significantly higher than those obtained under scenario Op1_6. The last scenario is recommendable.
* Considering an optimal use of the land, groundnut grown under the management system Op1_10 results in the highest gross margin for each land unit.

In Chapter 7 the interventions simulated in the intermediate and optimal scenarios will be presented in a toolkit format. The degree of success of one or a combination of interventions for specific crops on specific land units, for specific farmer groups, will be indicated by a qualitative rating, which is easy to use for the extension service.

6.1.4.2 Gross margin analyses of alternative crops

Very limited information is available regarding the production costs and the value of produce of the alternative crops discussed in Table 31. Some information for devil's claw, jugobean and sunflower is provided in Table 35.

Table 35. Gross margins (Pula/ha) alternative crops

CROP	PRODUCTION COSTS	VALUE OF PRODUCE	GROSS MARGIN
Devil's claw	0	2500-5000	2500-5000*
Jugobean	46**	98-163***	52-117
Sunflower	44**	82-125***	38-81

* Based on Edwards *et al.* (1989)
** Production costs comprise cost of seed, 105 kg/ha SSP fertilizer and spraying with Alphametrin
*** Based on BAMB producer prices 1994/95

Devil's claw is grown under traditional rainfall conditions similar to Chanoga AEA (450mm/yr) in the southern part of the country. It is a perennial and it is advised to harvest tubers in the second or third year. The average plant has a tuber system (primary and secondary tubers), which has an average weight of 1 kg. For a yield of 1000 kg, a plant density is required of 1000 plants/ha. This amount can probably increased up to 5000 plants/ha. Seeds can be collected from the veld; in the study area they occur in land unit LS1.

As this production system is close to veld product collection, no variable costs are incurred. Edwards *et al.* (1989) stress its labour intensiveness: 115 mandays per season are estimated, of which harvest (digging up of the roots) costs 40 mandays. Excluding family labour a gross margin of Pula 2500-5000/ha/2 years can be achieved, based on a market price of Pula 5.00/kg in 1989.

Both jugobean and sunflower achieve gross margins, that could be compared to the performance of the crops maize and cowpea grown under the improved management systems Im2 and Im3. The figures are positive, but the financial return per hectare is relatively low.

6.2 Evaluation of molapo farming

6.2.1 Production systems' analysis

Although the flooding history of the Boteti River shows a rather discouraging picture (a flood frequency of 20%, 1 out of the past 5 seasons), a qualitative evaluation of molapo farming production systems has been carried out.

Molapo farming is by its nature restricted to land unit AS1, the recent floodplain of the alluvial system. The molapo fields are situated on the lowest terrace levels adjacent to the channel of the Boteti River. The floodplain has a flat to almost flat morphology with maximum slopes of 2%. An estimated 97.5% of the floodplain is characterized by Areni-Eutric Fluvisols (soil unit F1, see Table 3), where the remaining 2.5% consists of Eutric Gleysols (soil unit G1). At places silcrete is outcropping and stones cover the surface. These spots are excluded as they are not suitable for any form of cultivation.

Factors relevant for molapo farming

Climate; start of rainy season and rainfall amount
Soil type; AWHC, fertility levels and workability
Flood recession dekad
Depth of ground water table below the root zone during the cropping cycle
Texture of subsoil in connection with capillary rise.

Production potential molapos

Maize is the main crop grown under molapo farming conditions. The characteristics of a fictive baseline management system are summarized in Table 36. The dekads of flood recession and planting are an approximation; no statistical analysis has been conducted. As molapo fields are usually smaller than dryland fields and often easier to plough (moist after the flood has receded), the baseline scenario simulates two planting opportunities. Due to the higher available soil moisture under molapo farming conditions, plant densities are two times as much as in the rainfed situation. Seeds are normally broadcasted and no fertilizer is used. The phosphorus content of the topsoils is 5 ppm, which is relatively high by nature. Weeding operations are often limited in effectiveness.

Table 36. Molapo farming management systems

CODE	FLOOD RECESSION	PLANTING DEKAD	PLANTING OPP'S	PLANT DENSITY	FERTILIZER (P level)	CROP HUSBANDRY
Bs5	AUG2-SEP2	AUG3-SEP3	2	30,000	none	broadcasting, improper weeding
Im4	AUG2-SEP2	AUG3-SEP3	1	50,000	10 ppm	harrowing, rowplanting, proper weeding

Although not many yield figures for on-farm molapo farming production systems are available, it is estimated that 300-600 kg/ha (4-8 70 kg bags) is a realistic figure under traditional crop husbandry, following management system Bs5.

Similar improvements in the management system as proposed for rainfed crop production (see Section 5.1.2.3) can be recommended to increase the molapo farming production. The most important are conducting a harrowing operation to create an even seedbed (especially in the case of clay rich topsoils), rowplanting and the use of inorganic fertilizer. The characteristics of an improved scenario are given in management system Im4, see Table 36.

Under controlled flooding conditions (flood control structures like bunds and sluices) in the Shorobe area, the Molapo Development Project recorded experimental maize yields from 1500-4100 kg/ha (Loos, 1985). On-farm crop trials held by the LUPSAD project included an experiment under molapo conditions near Mabele in the Chobe Enclave. Maize yields of 1770 kg/ha not fertilized (plant density 24,500), and of 2750 kg/ha after a SSP application of 200 kg/ha (plant density 41,800) were achieved (Bekker, 1995). Van de Pol and Bitsang (1995) simulated the performance of maize under various molapo circumstances for the Chobe Enclave with CYSLAMB. For fields situated on the floodplain they predicted yields from 1185-1400 kg/ha (shallow ground water level, 2 panting opportunities); from fields located in depressions yields of 1000 kg/ha are expected, while fields on slopes of a river channel could support a maize yield of approximately 2000 kg/ha.

Molapo farming can potentially achieve yields higher than dryland farming. When the physical conditions are met, farmers should be encouraged to cultivate a molapo field. Old fields could be used again after fences have been mended. Planting should preferably take place on a slight slope (in line with simulations of van der Pol and Bitsang, 1995), in order to prevent water logging and crop damage during the start of the rainy season. New fields should assure access to the public domain and leave a corridor in lateral way along the top (river bank) and bottom (channel) side of the field in order to maintain free passage of people and animals.

6.2.2 Financial analysis

Although no firm on-farm yield data are available gross margins can be calculated based on the assumed given yields. In Table 37 an example is worked out for maize, the most frequently grown crop under molapo farming systems. The same elements of the production process are included in the gross margin analysis as for rainfed cropping (see Section 6.1.4.1).

The gross margin for the baseline scenario Bs5 is similar to the gross margins achieved for maize grown under dryland farming conditions using the optimal management systems Op1, see Table 34. As maize can yield up to 2000-3000 kg/ha under improved crop husbandry and fertilizer use, which is considerably higher than under rainfed circumstances, the gross margin can raise upto 900-1375 Pula/ha. When the physical parameters are ideal, molapo farming can be very profitable.

Table 37. Gross margins (Pula/ha) maize crop under molapo farming

SCENARIO	PRODUCTION COSTS*	VALUE OF PRODUCE**	GROSS MARGIN
Bs5	3.36	143.57 - 287.14	140 - 280
Im4	60.03	957.14 - 1435.71	900 - 1375

* Bs5 only seed; Im4 seed, 175 kg SSP fertilizer/ha and 1 spraying operation with Alphametrin

** Bs5 based on yield estimate of 300-600 kg/ha; Im4 based on yield estimate of 2-3 tonnes/ha

6.3 Evaluation of horticulture, beekeeping and agroforestry systems

The major land uses horticulture, beekeeping and agroforestry are at present very under exploited, but could, in the framework of diversification and income creation, become of significant importance in the lives of rural families in the near future.

6.3.1 Horticulture production systems

The only source of surface water in the study area is the Boteti River. Due to the uncertain nature of its flooding regime, permanent horticultural projects using river water for irrigation are not viable. Year round production can only be achieved, when the enterprise is backed up by water supply through boreholes. Since the investment costs involved in drilling and developing a borehole are high (minimally Pula 40,000, depending the depth of a good aquifer), only commercial ventures could be thought of. Further feasibility studies, including FAP grant/loans could be considered for potential commercial projects or private individuals.

It could be noted here, that a number of residential plots has been successfully developed on the northern bank of the Boteti River. Gardens are well established and watered from boreholes. Adjacent to one plot is a semi-commercial citrus orchard established with an estimated 100-150 orange and lemon trees. This enterprise is also supported by a borehole and finds a market in Maun. These private undertakings prove, that horticulture is possible, when the water problems can be overcome. The soils are in general suitable, exceptions are the shallow and very heavy soil types.

For the small farmers in the study area, however, the best horticultural production system is a home vegetable garden. This could be accompanied by a backyard nursery and a small orchard.

6.3.1.1 Home vegetable garden

A variety of vegetables can be grown with minimal effort on a low input basis in a fenced corner of the yard. The worked out example in Table 38 is based on a total plot size of 100 m^2 and comprises the following vegetables: beetroot, cabbage, carrots, choumollier, onions, potatoes, spinach, and tomato, each on a patch of 12.5 m^2.

Table 38. Evaluation of a home vegetable garden

FINANCIAL PLAN HOME VEGETABLE GARDEN (1 season) plot size 100 m2

CROP REQUIREMENTS

CLIMATE: optimal growing period November–March (rainy season); second growing period March–July
SOIL: minimum depth 75 cm, texture sand–sandy loam, site not on bottom of depression (flood + salt risk)
WATER: November–March: 13,6 m3/month = 460 liter/day = 2,3 drums/day; due to rainfall the need can be reduced to 3–7 drums/week. March–July: 7,8 m3/month = 260 liter/day = 1.3 drum/day.

VALUE OF PRODUCE

CROP	YIELD (kg) from 12.5 m2	VALUE /kg (Pula)	VALUE /plot (Pula)
beetroot	45	1.98	89.10
cabbage	50	1.05	52.50
carrots	45	2.00	90.00
choumollier	60	0.73	43.80
onions	40	2.31	92.40
potatoes	30	1.34	40.20
spinach	120	0.76	91.20
tomatoes	20	2.22	44.40
		TOTAL	**543.60**

VARIABLE COSTS

ITEM	QUANTITY	PRICE (Pula)
seeds	25 g	20.00
fertilizer	10 kg	7.00
pesticides	400 ml	4.00
	TOTAL	**31.00**

FIXED COSTS

ITEM	QUANTITY	PRICE (Pula)
spade	1	35.00
watering can	1	20.00
perimeter fence	40 m	150.00
water drum 200 liter	1	250.00
wheelbarrow	1	100.00
shade netting 40%	100 m2	700.00 (optional)
	TOTAL	**1255.00**

GROSS MARGIN

Value of produce – variable costs = Gross margin: **P 512.60 / season**

NET FARM INCOME

Gross margin – 20% fixed costs = Net farm income: **P 261.60 / year of 1 season**
excluding shade netting NFI: P 401.60/year of 1 season

* Water requirements are monthly averages, based on Stoutjesdijk (pers. comm. in LUPSAD, 1995)
* Value of produce based on Retail prices for Francistown from Commodity Report June 1996, Crop Marketing Section MoA, Botswana
* Variable costs based on Maun market prices
* Fertilizer based on 1000 kg 2:3:2/ha, but can be replaced by (free) kraal manure or compost
* Pesticide: Alphametrin
* Fence costs based on FAP guidelines; other fixed costs based on Maun market prices

** Net farm income based on 20% of fixed costs, assuming a replacement interval of 5 years

Other commonly grown crops in horticultural projects are broccoli, egg plant, green pepper, lettuce, rape and swiss chard. The optimal growing period is from November-March. As this growing period is parallel with the rainy season, well drained soils are required and less irrigation water will be needed. The use of shade netting, due to the high temperatures, should be considered. A second crop can be planted from March-July; temperatures are moderate, only a slight frost risk exists in June and July. A fertilizer application of 10 kg (1000 kg/ha) of 2:3:2 is required.

The three main prerequisites for success are: fulfillment of the water requirements (possibly through water extraction from village stand pipes, river/wellpoints or a community boreholes), optimal crop husbandry practiced and financing of the fixed costs (initial expenses).

The financial analysis shown in Table 38 indicates the viability of the enterprise. Although extremely small scale, a potential gross margin of Pula 512.60 can be expected per growing season, in case all produce would be sold. The majority is, however, meant for home consumption. This will enrich the family diet and increase the vitamin intake from the one hand, and lead to savings on the household budget for the purchase of fresh vegetables on the other hand. Possible modest surpluses can be sold in the village and contribute to the household cash income.

When assumed, that all assets will have to be replaced each five years, a net farm income out of this production system for one growing season per year of Pula 261.60 including, and Pula 401.60 excluding shade netting can be achieved.

6.3.1.2 Backyard nursery and orchard

Backyard nurseries can be an attractive, alternative source of (cash) income for rural households. With relatively few inputs and minimal effort, a reasonable sum can be generated. Variable costs (seeds, plastic sleeves, fertilizer and pesticides) are very modest and amount at maximum Pula 1.00/raised seedling. Seedlings can be sold in the settlements at a price of Pula 2.00 a piece.

Regarding orchards, Sims (1981) recommends citrus, guava and papaya as most suitable fruit trees in the northern zone of Botswana. Other promising trees are mango, morula and mulberry. Most fruit trees only start producing in their 5th year. But the produce of a few trees is too much for one family's home consumption and some surplus can be sold in the village, thus contributing to the household cash income.

No financial plan has been prepared for the production systems backyard nursery and orchard. For both activities it is imperative, that the farmer has access to a permanent water source, the seedlings are well protected and looked after and a modest starting capital is available to cover the initial fixed costs.

6.3.2 Beekeeping production systems

In the light of diversification of income generating activities, an analysis was made of a small scale beekeeping project by the Beekeeping Section, RAO Maun.

Ideal bee habitats contain trees and plants, that flower all year round. Suitable natural species are *Acacia erubescens*, *A. mellifera*, *A. nigrescens*, *A. tortilis*, *Combretum imberbe*, *Dichrostachys cineria*, *Diospyros mespiliformis*, *Terminalia sericea*, *Tribulus terrestris* and *Zizyphus mucronata*. Sown flowers or planted lucern and sunflower near an apiary will enhance honey production.

As bees need water to cool their hives, an apiary should be located in the vicinity of a permanent water source. If no water source nearby, the beekeeper can provide water to the colonies. During the winter months from May-July, a sugar syrup (concentration sugar-water of 1:1) can be given to the bees as supplementary feed.

Comb honey (wax + honey) is a much liked product amongst the local population and is assumed as output of this production system. Bottled honey production per hive is much lower and more costs are involved. Each hive (containing 1 colony) can produce 30 kg of comb honey per harvest. Harvest time is in the months of April/May and in November/December.

As no other variable cost than for supplementary feeding are required a gross margin, based on two harvests per hive per year of Pula 1428.50 can be achieved. The net farm income, based on a replacement interval of 5 years, amounts then Pula 1350.50 per year, see Table 39 for a financial plan for 2 hives (2 colonies).

Care should be taken for attacks by ants. One way of protecting hives from ant attacks is placing the legs of the hives in a tin filled with oil.

Table 39. Evaluation of a beekeeping project

FINANCIAL PLAN BEEKEEPING PROJECT (1 year) — 2 hives

REQUIREMENTS

LOCATION: Apiary should be located at least 100 m away from houses/people to avoid disturbances. The apiary should be protected by wind breaking trees/shrubs. Hives should be placed in the shade all day for cooling and to protect the colonies against attacks by pirates.
VEGETATION: Apiary should be located in natural bee habitat or surrounded by sown flowers.
WATER: A permanent water source should be available within 2–3 km from the apiary.

VALUE OF PRODUCE

ITEM	YIELD (kg) from 1 hive	VALUE (Pula/kg)	VALUE hive/harvest (Pula)	VALUE 2hives/2harvest (Pula)
comb honey	30	12.00	360.00	1440.00
			TOTAL	**1440.00**

VARIABLE COSTS

ITEM	QUANTITY	PRICE (Pula)
sugar	5 kg	11.50
	TOTAL	**11.50**

FIXED COSTS

ITEM	QUANTITY	PRICE (Pula)
bee hive	2	250.00
bee smoker	1	90.00
bee veil	1	50.00
	TOTAL	**390.00**

GROSS MARGIN

Value of produce – variable costs = Gross margin: **P 1428.50 / year**

NET FARM INCOME

Gross margin – 20% fixed costs = Net farm income: **P 1350.50 / year**

* sugar is needed for supplementary feeding during winter
* Prices of fixed costs for 1996 – items available from Beekeeping Office RAO, Maun

** Net farm income based on 20% of fixed costs, assuming a replacement interval of 5 years

6.3.3 Agroforestry systems

This section is based on information compiled by the Forestry Section, RAO Maun. Further reading can be done in Kerkhof (1992), Otsyina and Walker (1990) and Simute (1992). Several recommended species have been found through ECOCROP 1 (FAO, 1994).

Agroforestry systems can have a wide range of applications. The specially planted trees and shrubs can be used as soil conservation measures, for soil fertility improvement, as source of fodder, fuelwood and building materials and for fruits and medicine. Resulting from the observed signs of wind erosion, specifically on arable lands, a brief evaluation is made of the possibility to mitigate this process by using agroforestry techniques. Three options are considered: hedge rows, tree wind breaks and life perimeter fences.

Hedge rows

Hedge rows can serve to decrease the erosion power of storms and to improve the nutrient status of soils. When pruned on a yearly basis, hedge row species can provide green manure and nitrogen to the soil by using branches and leaves as mulch. Cuttings can also be used as fodder. Cultivation of crops between rows of hedges is also referred to as alley farming. Some suitable species are:

* Cassia (*Cassia spectablis*) - exotic
* Leucaena (*Leucaena leucocephala*) - exotic
* Pigeon pea (*Cajanus cajan*) - exotic
* Sesbania (*Sesbania sesban*) - indigenous

Tree wind breaks

At maximum canopy, suitable species to form wind breaks are the following:

* Bluegum (*Eucalyptus camaldulensis*) - exotic
* Cassia (*Cassia spectablis*) - exotic
* Gum arabic tree (*Acacia senegal*) - exotic
* Mothabakgosi (*Acacia nilotica*) - indigenous
* Neem (*Azadirachta indica*) - exotic
* Pepper tree (*Casuarina* sp.) - exotic
* Red bluegum (*Eucalyptus tereticornis*) - exotic
* Silky oak (*Grevillea robusta*) - exotic
* Syringa (*Melia azerdarach*) - exotic

Life perimeter fences

A life perimeter fence consisting of thorny species has a crop protection function and will reduce the need for (the maintenance of) a commonly used bush fence. Hence, the pressure on the surrounding natural vegetation will be considerably lowered. In addition it will function as a wind break and some species improve the soil nutrient status through the fixation of nitrogen. The life perimeter fence can serve as a source of fodder and green manure. Some suitable species:

* Kei apple (*Dovyalis caffra*) - regional
* Mohosho (*Faidherbia albida*) - indigenous
* Mokgalo (*Ziziphus mucronata*) - indigenous
* Moshu (*Acacia tortilis*) - indigenous
* Sisal (*Agave sisalana*) - exotic

Two designs for agroforestry based protection systems for arable fields are discussed below. The first system is based on a combination of hedge rows with tree wind breaks, whereas the second system combines tree wind breaks with life perimeter fencing. The proposals are worked out on a per hectare basis, assuming a plot of 100x100m. Provided are numbers of shrubs and trees, plot layouts and labour and cost estimates. For a financial evaluation of both systems see Table 40.

Agroforestry systems Af1: Hedge rows with tree wind breaks

The wind breaks will settle the predominant easterly winds throughout the year, assisted by hedges of nitrogen fixating species. It is proposed to plant two wind breaks, one on the wind facing end of the field and one halfway. Each wind break should consist of 50 trees with an inter-tree spacing of 2m. On the lee side of each wind break two hedge rows are planted, at an equidistance from the wind break and each other. Each hedge row should consist of 50 shrubs/small trees with an inter-plant spacing of 2m.

The wind break trees are budgeted for a lifespan of 20 years. The hedge row species are replaced after 10 years. Pigeon pea can be sown directly and is supposed to be replaced every 2 years.

The labour requirements can be broken down into 8 mandays for planting preparation (hole digging), 3 mandays for the actual planting and 15 mandays/yr during the first 3 years for watering and monitoring. Each 10 years the hedge rows have to be replaced, requiring 17 mandays/1 year, while each 20 years the wind break trees have to be coppiced or completely removed. This will require an estimated 20 mandays/1 year. Table 40 shows the total of fixed costs involved in this system, including the discounted costs for replacement of the hedge rows after 10 years.

Agroforestry system Af2: Tree wind breaks with life perimeter fencing

The wind breaks will settle the predominant easterly winds throughout the year, assisted by a life fence around the entire field. It is proposed to plant three wind breaks, one on the wind facing end of the field and two each at one third of the field. Each wind break should consist of 50 trees with an inter-tree spacing of 2m. Around the field a row of shrubs/small trees is planted. This life perimeter fence should consist of 200 shrubs/small trees with an inter-plant spacing of 2m. The wind break trees and the life fence are budgeted to have a lifespan of 20 years.

Table 40. Financial plan for agroforestry systems Af1 and Af2

FINANCIAL PLAN AGROFORESTRY SYSTEMS (1 hectare plot)

REQUIREMENTS

SOIL: deep, texture sand–sandy loam, site not on bottom of depression (flood + salt risk)
WATER: estimated for year 1–3 for both sytems 50 liter/tree/year: system Af1 15m3/yr; system Af2 17.5m3/yr

FIXED COSTS

SYSTEM Af1				**SYSTEM Af2**			
ITEM	QUANTITY	UNIT PRICE (Pula)	TOTAL (Pula)	ITEM	QUANTITY	UNIT PRICE (Pula)	TOTAL (Pula)
2 wind breaks @ 50 trees	100	1	100	3 wind breaks @ 50 trees	150	1	150
4 hedge rows @ 50 shrubs	200	1	200	1 perimeter fence @ 200 shrubs	200	1	200
spade	1	35	35	spade	1	35	35
watering can	1	20	20	watering can	1	20	20
water drum 200 liter	1	250	250	water drum 200 liter	1	250	250
siccators/saw	1	75	75	siccators/saw	1	75	75
		INITIAL TOTAL	**680**			**TOTAL**	**730**
after 10 years:							
4 hedge rows @ 50 shrubs	200	4	800				
(discounted over 10 years at 15% interest)							
		END TOTAL	**1480**				

The labour requirements can be broken down into 9 mandays for planting preparation (hole digging), 3 mandays for the actual planting and 15 mandays/yr during the first three years for watering and monitoring. Each 20 years the wind break trees and the perimeter fence species have to be coppiced or replaced. This will require an estimated 20 mandays/1 year. Table 40 indicates the fixed costs of this system.

Observations

When comparing the two agroforestry systems, it appears, that system Af1 is initially the cheapest, but has the replacement costs of the hedge rows after 10 years. An advantage of system Af1 above Af2 is the higher chance of nitrogen fixation in the field (5 rows of hedges and wind breaks in the field for Af1, against 2 wind breaks for Af2). On the other hand does system Af1 take up more space than Af2, and thus leaves less room for crops (given a field of 100x100m). System Af2 is in the long run the cheaper, especially when the quantity and value of coppiced or felled logs is taken into account. It also requires less maintenance.

The multi-purpose character of the species used in these agroforestry systems can benefit farmers in various ways. Field trials should prove their effectiveness as anti-wind erosion measure. The utilization of several species for fodder can have a positive spin-off on arable crop production and livestock enterprises, and hence increase the cash income of farming households.

The most serious limitations for agroforestry systems in most parts of Botswana is the water situation. The above two proposals can only be considered, if the interested farmer has access to a reliable water source. A second prerequisite for success is an adequate protection against livestock and smallstock of the newly planted seedlings.

The factor motivation comes into play, where the labour requirements are considered. In itself the amount of labour needed is not excessive, but a certain level of dedication to carry out watering and pruning operations throughout the year is required. In this respect, an additional handicap is the often temporary stay at the lands, for the cropping season only. Where any agroforestry project asks for regular monitoring during the first three years.

6.4 Evaluation of livestock production systems

For the assessment of the performance of livestock production systems two factors are evaluated: the grazing capacity of the rangeland and the animal condition. The Animal Production and Range Assessment Model for Botswana was designed to simulated the above. A separate spreadsheet was used to conduct a simple financial analysis of the main recognized production systems.

6.4.1 Introduction to APSRAMB

The Animal Production and Range Assessment Module for Botswana (APSRAMB) consists of two modules: a biomass and a livestock module, which will be briefly discussed below. For information on the Theory and the User Manual reference is made to Powell and Pulles (1996), Validation of the program is discussed in Powell (1996), and Programmer's reference in Pulles (1996).

6.4.1.1 Biomass module

Based on the vegetation data stored in the Botswana Vegetation Database and making use of climatic and soil data, this part of the program determines the vegetative biomass production for each vegetation unit in terms of kg Dry Matter/ha/yr. Outside the program, this figure can be multiplied with the extent of the unit to achieve the total biomass production in tonnes Dry Matter/yr for each vegetation unit.

The biomass module is run for a pre-selected range of years, making use of the average synoptic and actual dekadal rainfall figures for the mentioned period. For each month of each selected year the performance of the range is evaluated. The produced biomass is separated according to the stem, leave, root and total production for the tree, upper bush and lower bush layers and in aerial, root and total production for the herbaceous layers under and away from canopy.

Two types of output files are created by the program. The first file, described as the biomass yield statistics file, shows some statistical analyses of the generated biomass data. Per evaluated combination of vegetation type and soil, the probabilities (100%, 75%, 50%, 25% and 0%) of achieving an amount of biomass over the selected range of years, the average amount of biomass produced over the selected range of years and the total amount of biomass produced over the selected period are given for the recognized categories of biomass.

The second file with extension '*.*bio*', described as transfer file, contains biomass figures on a monthly basis (per hectare) for all years evaluated for all biomass categories. The program calculates a monthly digestibility figure for each vegetation type, based on the species composition of the unit. For each combination of vegetation type and soil, a separate '*.*bio*' file is generated. These files can serve as direct input from the biomass module into the livestock module of the program. The model has, however, also an option to aggregate the biomass data from combinations of vegetation and soil units into a transfer file for one land unit or to aggregate the biomass from several land units into a transfer file for an entire grazing area.

The digestibility figures in the transfer files are used to indicate how the produced herbaceous biomass is converted in animal biomass (cattle weight gain).

The available biomass for cattle is determined by the aerial biomass of the herbaceous strata under and away from canopy. The available biomass for browsing (for goats, and cattle in extremely dry years) consists of the biomass produced by the leaves of the lower bush layer (upto 1.50m).

The production potential of a land unit under extensive grazing expressed in biomass yield per annum can be translated into the carrying capacity and the grazing capacity of the land unit. The carrying capacity is the minimum number of hectares necessary to satisfy the dry matter requirements (Dry Matter Intake, DMI) of one livestock unit (LSU). In this study a livestock unit is considered a mature animal with a weight of 450 kg. The grazing capacity or stocking rate, reflects the maximum amount of LSUs that a land unit can support in a sustainable way. Caution should be practiced, when using these two parameters, as the digestibility of the produced biomass (not reflected in the carrying and grazing capacities) determines the efficiency of the weight gain.

A parameter, reflecting the loss of produced herbaceous biomass, due to e.g. termite activity, fire and small game species, can be set in the *biomass.ini* file in the program, when appropriate. The biomass module has also been used for the assessment of the fuelwood reserve and the production of several veld products in the study area (see Section 6.5).

6.4.1.2 Livestock module

This part of the program uses the biomass production and digestibility figures provided by the transfer files of the biomass module as input for the simulation of the performance of pre-defined livestock production systems, based on the entered management parameters. The module is not perfected yet and needs further validation and development. This module of APSRAMB estimates live weight gain/loss, conception and calving rates for breeding cows, milk production and mortality rates. A sales component calculates the output of the evaluated production system in terms of sold cattle. Sales conditions (category, age, months of sales, live weight condition) are defined in the management system. The module further looks into the dynamics of any given starting herd over time and generates a herd projection for the set period, under the given biomass input and management parameters.

The results of simulations of the livestock module are written to four types of files.

The HERDLOG file provides detailed information on a monthly basis for each animal in the herd, on amongst others: age, weight, forage intake, weight gain/loss, condition, metabolizable energy consumed, milk production, pregnancy and number of produced calves.

The HERDSTAT file gives a summary of the number of cows in the herd, the number of calvings and the calving rates. The figures are calculated on a monthly basis.

Data on the herd development are stored in the DEFAULT.liv file. It furnishes information on an monthly basis about the number and category of animals sold, died, transfers of animals from one category to another and an existing stock count.

A special file registers the sales information, the HERDSALE file. The age, weight, month and year of the sale of each animal sold of the herd is stored in this file. Based on the value of the initial herd, the value of the sold animals and the value of the salvage herd, a financial analysis can be carried out, resulting in an estimation of the financial viability of each production system evaluated. Input figures are not yet incorporated in the module, but can be added on a separate spreadsheet.

6.4.1.3 Minimum datasets

In order to be able to run the APSRAMB program, minimum datasets for location, climate, vegetation and soil are required for the biomass module, whereas breed characteristics, data on animal categories, herd composition and management system are needed for the livestock module. Table 41 below shows the required parameters.

Table 41. Minimum datasets for the use of APSRAMB

BIOMASS MODULE		LIVESTOCK MODULE		
LOCATION	synoptic station	BREED CHARACTERISTICS	parameters specific to each defined breeds (for both male and female animals)	
	rainfall station			
	latitude	ANIMAL CATEGORIES	category	
	longitude		breed	
CLIMATE	sunshine hours		sex	
	maximum temperature		minimum age (months)	
	minimum temperature		maximum age (months)	
	rainfall frequency		intake coefficient	
	dekadal rainfall	HERD COMPOSITION	breed	
	potential evapotranspiration		category	
			number	
	latitude		age	
VEGETATION	canopy cover percentages of all strata and the total for each vegetation unit	MANAGEMENT	land	grazing area
				daily walking distance
SOIL	see Tables 3 and 4		sales options to be specified by category	percentage remaining
				minimum age
				first month
				last month
			breeding season (months)	

6.4.2 Biomass production

6.4.2.1 Range biomass production calculated by APSRAMB

The biomass production of the range in the Chanoga AEA was calculated by APSRAMB, based on the species composition and the percentage canopy cover of the species in each vegetation unit. For the calculations the synoptic and rainfall data of the Maun weather station were used. The range of years selected was 1974-1993, similar to the simulations of rainfed arable farming with CYSLAMB. The figures presented in this section reflect the **average** aerial biomass production (dry matter) over the taken range of years. No biomass loss factor was simulated.

Biomass per vegetation unit

Most vegetation units occur on several soil types. Appendix III depicts a table of soil types and their extent (in hectare and percentage) for each vegetation unit. All combinations of vegetation units and soil types of Appendix III were run in APSRAMB. Subsequently, the total biomass figure for each vegetation unit was estimated, based on a weighting according to the extent of each soil unit in a vegetation unit (the column Area in % of the Vegetation Unit, in Appendix III).

Table 42a shows the comprehensive aerial biomass production figures in kg dry matter/ha/yr for the tree, upper and lower bush and herbaceous strata of all 11 vegetation units (see Section 3.6 for characteristics of the vegetation units).

Table 42b summarizes the biomass figures according to use on a per hectare basis. The biomass produced by both herbaceous strata (under and away from canopy) forms the total biomass available for grazing. The biomass produced by the leaves of the lower shrub layer (upto 1.50m above ground) is available for browsing. The total biomass not used for grazing nor browsing is also reflected ('OTHER'). This column consists of the addition of the biomass produced by tree and upper bush stems and leaves, and the lower bush stems.

Table 42c depicts the total aerial biomass production for each vegetation unit in the study area in tonnes of dry matter/yr in summarized format according to use group. Essentially, the per hectare figures of Table 42b were multiplied by the total extent in hectares of each vegetation unit.

Table 42a. Comprehensive aerial biomass production per vegetation unit (kg Dry Matter/ha/yr)

a. AERIAL BIOMASS (kg Dry Matter/ha/yr) COMPREHENSIVE

VEG. UNIT	TOTAL	TREE stem	TREE leaves	UPPER BUSH stem	UPPER BUSH leaves	LOWER BUSH stem	LOWER BUSH leaves	HERBS under	HERBS away
V1	5833	0	0	0	0	0	0	0	5833
V2	4425	0	0	0	0	0	0	0	4425
V3	1220	35	68	82	158	35	68	0	774
V4	4293	76	147	137	265	426	824	332	2086
V5	5127	80	155	113	218	515	994	499	2553
V6	3367	98	190	169	326	520	1004	158	902
V7	3330	166	322	115	221	208	402	356	1540
V8	2604	257	497	114	221	157	304	147	907
V9	3334	200	387	160	309	267	515	385	1111
V10	3129	216	418	187	362	302	585	27	1032
V11	2387	210	406	140	270	210	406	372	373

Table 42b. Summary aerial biomass production per vegetation unit (kg Dry Matter/ha/yr)
Table 42c. Total aerial biomass production per vegetation unit (tonnes Dry Matter/yr)

b. AERIAL BIOMASS (kg Dry Matter/ha/yr) SUMMARY							c. AERIAL BIOMASS (tonnes Dry Matter/yr) TOTAL					
VEG. UNIT	TOTAL	GRAZE *)	BROW **)	GR+BR ***)	OTHER ****)	AREA (ha)	VEG. UNIT	TOTAL	GRAZE *)	BROW **)	GR+BR ***)	OTHER ****)
V1	5833	5833	0	5833	0	52	V1	303	303	0	303	0
V2	4425	4425	0	4425	0	667	V2	2951	2951	0	2951	0
V3	1220	774	68	842	378	359	V3	437	278	24	302	135
V4	4293	2418	824	3242	1051	37744	V4	161971	91198	31089	122287	39684
V5	5127	3052	994	4046	1081	1493	V5	7655	4557	1484	6041	1614
V6	3367	1060	1004	2064	1303	4481	V6	15088	4750	4499	9249	5839
V7	3330	1896	402	2298	1032	1646	V7	5482	3121	662	3783	1699
V8	2604	1054	304	1358	1246	17079	V8	44473	18001	5192	23193	21280
V9	3334	1496	515	2011	1323	10929	V9	36437	16350	5628	21978	14459
V10	3129	1059	585	1644	1485	2710	V10	8479	2870	1585	4455	4024
V11	2387	745	406	1151	1236	928	V11	2215	691	377	1068	1147

*) Total aerial biomass available for grazing – herbaceous layers under and away from canopy
**) Total aerial biomass available for browsing – lower bush (leaves)
***) Total aerial biomass available for grazing and browsing
****) Total aerial biomass produced by trees (stem+leaves), upper bush (stem+leaves) and lower bush (stem) not used for grazing or browsing

Observations

* The highest biomass production of 5.8 tonnes/ha/yr is achieved by the vegetation unit V1 (*Phragmites australis* reeds) along the Boteti River.
* Vegetation unit V5 (*Colophospermum mopane* and *Grewia* spp. shrubs) produces 5.1 tonnes/ha/yr, of which 79% is attributed to the herbaceous strata and the leaves of lower shrubs. The units V2 and V4 reach a dry matter production of 4.4 and 4.3 tonnes/ha/yr. Unit V2 consists of grasses and other floodplain species, while V4 is a typical sandveld unit.
* Most vegetation units produce a total amount of 2.4-3.4 tonnes of dry matter/ha/yr. These units are mainly characterized by a savanna to dense savanna structure, so more of the total biomass production is produced by the tree and upper bush layers. The biomass available for grazing and browsing in these units constitutes approximately 60% of the total.
* Unit V3, which consists of halophytic grass and forb species alternated with clumps of trees, produces relatively little biomass (1220 kg dry matter/ha/yr), due to its occurrence in pans.
* The vegetation units V4, V8 and V9 occupy 86% of the study area and hence produce most of the total biomass. The units V1 (floodplain) and V3 (pans) have the smallest extent and produce comparatively the smallest amounts of total biomass. It can be noted, that approximately 80% of the unit V1 (*Phragmites australis* reeds) was burned down. The biomass production was reduced accordingly by decreasing the extent of the unit by 80%.
* The total amount of biomass produced on a yearly basis in the entire Chanoga AEA is 285,500 tonnes of dry matter, of which 50% is grazing (145,000 tonnes), 18% browsing (50,500 tonnes) and 32% for livestock not edible biomass (89,900 tonnes).

Biomass per land unit

For range assessment purposes, the biomass production figures of the individual vegetation units have been transferred to biomass yields of land units. All combinations of vegetation type and soil unit for each land unit have been evaluated. A weighting, based on the extent of each combination of vegetation type and soil unit in a land unit, leads to the total of produced biomass per land unit. Appendix IV (area of vegetation and soil units per land unit) formed the basis of this exercise.

Table 43a shows the comprehensive aerial biomass figures for the tree, upper and lower bush and herbaceous strata of all 10 land units (see Section 3.7 for characteristics of the land units).

Table 43b summarizes the biomass figures according to use on a per hectare basis. The biomass produced by both herbaceous strata (under and away from canopy) forms the total biomass available for grazing. The biomass produced by the leaves of the lower shrub layer (upto 1.50m above ground) is available for browsing. The total biomass not used for grazing or browsing is also reflected ('OTHER'). This column consists of the addition of the biomass produced by tree and upper bush stems and leaves, and the lower bush stems.

Table 43c depicts the total aerial biomass production for each land unit in the study area in tonnes of dry matter/yr in summarized format according to use group. Essentially, the per hectare figures of Table 43b were multiplied by the total extent in hectares of each land unit.

Table 43a. Comprehensive aerial biomass production per land unit (kg Dry Matter/ha/yr)

a. AERIAL BIOMASS (kg Dry Matter/ha/yr) COMPREHENSIVE

LAND UNIT	TOTAL	TREE		UPPER BUSH		LOWER BUSH		HERBS	
		stem	leaves	stem	leaves	stem	leaves	under	away
AS1	3274	66	127	46	88	70	136	157	2584
AS2	3179	206	400	150	290	246	475	350	1062
AS3	2968	221	427	122	235	191	369	253	1150
AS4	1437	67	130	76	147	68	132	103	714
LS1	3971	102	198	138	267	378	732	339	1817
LS2	2858	184	355	132	255	242	468	246	976
LS3	1895	42	81	72	138	221	426	131	784
SV1	4022	102	195	140	270	393	761	305	1856
SV2	3417	186	359	136	263	311	602	222	1338
SV3	3231	118	228	122	236	318	614	210	1385

Table 43b. Summary aerial biomass production per land unit (kg Dry Matter/ha/yr)
Table 43c. Total aerial biomass production per land unit (tonnes Dry Matter/yr)

b. AERIAL BIOMASS (kg Dry Matter/ha/yr) SUMMARY

LAND UNIT	TOTAL	GRAZE *)	BROW **)	GR+BR ***)	OTHER ****)	AREA (ha)
AS1	3274	2741	136	2877	397	1383
AS2	3179	1412	475	1887	1292	8266
AS3	2968	1403	369	1772	1196	2829
AS4	1437	817	132	949	488	569
LS1	3971	2156	732	2888	1083	3457
LS2	2858	1222	468	1690	1168	916
LS3	1895	915	426	1341	554	168
SV1	4022	2161	761	2922	1100	36694
SV2	3417	1560	602	2162	1255	23209
SV3	3231	1595	614	2209	1022	597

c. AERIAL BIOMASS (tonnes Dry Matter/yr) TOTAL

LAND UNIT	TOTAL	GRAZE *)	BROW **)	GR+BR ***)	OTHER ****)
AS1	4528	3791	188	3979	549
AS2	26278	11672	3926	15598	10680
AS3	8396	3969	1044	5013	3383
AS4	818	465	75	540	278
LS1	13728	7453	2531	9984	3744
LS2	2618	1119	429	1548	1070
LS3	319	154	72	226	93
SV1	147572	79289	27936	107225	40347
SV2	79305	36206	13972	50178	29127
SV3	1929	952	367	1319	610

NB. For explanation of notes, see Table 42.

Observations

* On a per hectare basis the land unit LS1 and SV1 achieve the highest total biomass production of approximately 4 tonnes dry matter/ha/yr.
* Most land units yield a total biomass of 2.8-3.4 tonnes of dry matter/ha/yr.
* The land units AS4 (1437 kg dry matter/ha/yr) and LS3 (1895 kg dry matter/ha/yr) are the lowest in biomass production. This is related to their geomorphological nature of pans and their soils characterized by shallow to very shallow petrocalcic horizons.
* The biomass production of land unit AS1 constitutes for 84% of grazing. This is somewhat misleading, as the majority of the 3.3 tonnes dry matter is attributed to *Phragmites australis* reeds, which are barely eaten by cattle and goats.
* The highest amounts of biomass for grazing are produced on the land units LS1 (2156 kg dry matter/ha/yr) and SV1 (2161 kg dry matter/ha/yr), which on both land units is approximately 54% of the total biomass produced. The lowest amount of available grazing biomass of 817 kg dry matter/ha/yr is found on the pans of land unit LS3.
* Most other land units have a biomass production for grazing between 1200-1600 kg dry matter/ha/yr, which is approximately 45% of the total biomass produced. The amount of browse generally varies from 350-750 kg/ha/yr, while the rest group has a biomass increment of 1000-1300 kg/ha/yr.
* The highest yearly total amounts of biomass (dry matter) are produced on the largest land units SV1 (147,500 tonnes), SV2 (79,300 tonnes) and AS2 (26,300 tonnes). The lowest production is achieved on the land units AS4 (820 tonnes), LS3 (320 tonnes) and SV3 (1930 tonnes), which are all pans with a limited extent.

Carrying capacities and grazing capacities

The previous two sections indicate, that on average a considerable amount of biomass was produced in the Chanoga AEA in the period 1974-1993. However, a straight forward calculation of the carrying capacity and the grazing capacity (stocking rate) of each land unit shows a too optimistic picture, due to the low digestibilities of the present grass species. The dry matter available for grazing in most vegetation units has a digestibility fraction between 0.3-0.6. This severely limits an optimal use of the range.

The yearly Dry Matter Intake requirement of a livestock unit is simulated as 2.5% of the live weight of a LSU (450 kg) * 365 days, equaling 4106 kg of dry matter/yr. Although this dry matter requirement can be fulfilled in most years, cattle struggle to gain weight, due to the low nutritive value of the available biomass. As the carrying capacity and the grazing capacity do not reflect this conflicting situation, no further evaluation of the land units has been done. No information can be given on appropriate stocking rates and possible room for herd expansion.

Grazing areas

As cattle roam around across borders of land units, comparing carrying capacities on a per land unit basis has only got an academic value. Considering the two existing cattle management systems (ECv - small herds around the villages and ECc - medium sized herds around the cattleposts), two large grazing areas have been evaluated in the Chanoga AEA:

- Area A: around the villages and the Boteti River (management system ECv), consisting of land units AS1, AS2, AS3, AS4, LS1, LS2, LS3 and 30% of (SV1, SV2, SV3)

- Area B: around the cattleposts in the sandveld (management system ECc), consisting of 70% of land units (SV1, SV2, SV3).

It is assumed, that cattle belonging to system ECv migrate between the Boteti River for watering and the sandveld for grazing. These animals utilize the grazing along the river (the alluvial land units), on the lacustrine system and only the southern portion of the sandveld.

For this last reason, 30% of the biomass produced on the sandveld as a whole is included in the biomass available in grazing area A. The remaining 70% of the sandveld provides the biomass for grazing area B. The animals watered and kraaled at the cattleposts stay in the sandveld and do not normally utilize grazing area A. The 30%-70% partitioning of the sandveld is arbitrary, but is an approximation; with advanced GIS techniques the biomass available in both blocks can be more accurately assessed.

As the amount of biomass produced and the number of animals grazing and browsing are known (see Table 44), the present stocking rates for both grazing areas A and B can be evaluated.

On top of the resident numbers of livestock in both grazing areas, a number of cattle and accompanying horses and donkeys, trekked through the AEA en route to the Shorobe Quarantine Camp, has to be catered for as well. An estimated 250 LSUs is assumed to make use of the range on a yearly basis, bringing the actual grazing pressure (before the CBPP outbreak) to 3120 and 1132 LSUs in the grazing area A and B, respectively.

After subtracting the Dry Matter Intake requirement of the existing stock from the available grazing biomass in both grazing areas, a biomass surplus remains. The surplus amounts 50,745 tonnes of dry matter/yr in grazing area A and 76,865 tonnes of dry matter/yr for grazing area B. For reasons discussed above no assessment has been done of the sustainability of the present or potential stocking rates of both grazing areas.

Table 44. Evaluation of grazing areas A and B

PARAMETERS	GRAZING AREA A villages 35945 ha			GRAZING AREA B cattleposts 42350 ha			REMARKS
LAND UNITS	AS1, AS2, AS3, AS4, LS1, LS2, LS3 30% of area of (SV1, SV2, SV3)			70% of area of (SV1, SV2, SV3)			
AVAILABLE BIOMASS (tonnes Dry Matter/yr) (a)			GRAZING 63557			GRAZING 81513	total aerial biomass available for grazing (herb layers under and away from canopy)
RESIDENT LIVESTOCK	TYPE	NUMBER	LSU	TYPE	NUM	LSU	1 LSU has a live weight of 450 kg
	cattle goats donkeys	2445 3435 1165	1711 343 816	cattle goats	1050 1470	735 147	1 head of cattle average 0.7 LSU 1 goat average 0.1 LSU 1 donkey average 0.7 LSU
TREKKING CATTLE (estimated LSUs)			250			250	trekked to the Shorobe Quarantine Camp
ACTUAL GRAZING PRESSURE (b) (LSUs)	TOTAL		3120	TOTAL		1132	existing number of LSUs in the study area (before CBPP eradication)
REQUIRED DRY MATTER INTAKE (c) (tonnes Dry Matter/yr)			12812			4648	(b) * 2.5% of liveweight of 1 LSU * 365 days
BIOMASS SURPLUS (d) (tonnes Dry Matter/yr)			50745			76865	(a) – (c)

6.4.2.2 Stover production calculated by CYSLAMB

With help of CYSLAMB the arable waste available for cattle after crop harvesting was calculated. Starting point were the area cultivated and the seeds distributed during the 1993/94 cropping season. From the 872 ha, 84% was planted with maize, 13% with sorghum and 3% with millet. By running CYSLAMB for these three crops under the baseline management system Bs3 (late planting, 3 plant opportunities), the amount of stover produced was calculated by deducting the grain yield from the total produced net biomass. It is assumed, that 50% of the crop residue is lost due to soiling, termite activity etc.

Weighted according to the hectarage of the grown crops, the total stover production was approximately 160,000 kg Dry Matter, which is an average of 185 kg/ha. The baseline area of land under cultivation amounts 1543 ha, or 2% of the total study area. During the 1993/94 season 671 ha was fallow and the area under crops covered approximately 1% of the AEA. The total stover production of 160 tonnes/yr is negligible (0.1%) compared to the yearly biomass produced by the range.

6.4.3 Evaluation of standard cattle production systems with APSRAMB

6.4.3.1 Factors relevant for the use of the livestock module of APSRAMB

Before evaluating the performance of a given starting herd, a number of parameters has to be set in different files in the program.

Constant parameters

The following characteristics remain constant during a batch of evaluations:

* In the *livestock.ini* file all parameters are kept at the default values, except for the degradation factor of standing biomass (set at 14 months) and the initial biomass, available at the start of the evaluations (set at 1000 kg/ha).

* The breed characteristics in the *breed.brd* file, like calving rates, mortality rates, milk production etc. are kept at the default values, as they are breed specific.

* The cattle categories, from which a herd can be compiled, are defined in the *category.ctg* file and shown below. All animals have an Intake Coefficient of 0.0619, while the minimum and maximum age (in months) are indicated between brackets.

Heifer calf	(0-12)	Steer 1yr	(12-24)
Heifer 1yr	(12-24)	Steer 2yr	(24-36)
Heifer 2yr	(24-36)	Steer 3yr	(36-48)
Cow	(36-144)	Steer 4yr	(48-60)
Cull cow	(144-9999)	Steer 5yr	(60-72)
Bull calf	(0-12)	Steer 6+yr	(72-9999)

Variable parameters

The following characteristics can vary, depending the grazing area utilized, the number and category of animals involved and the management system practiced:

* The biomass '*.*bio*' transfer files generated by the biomass module of the program.

* Supplementary feed defined in the '*.*sup*' files.

* The herd definitions stored in the '*.*hrd*' files.

* The management boundary conditions concerning the land (extent of the grazing area), the sales decisions and the breeding season are set in the '*.*man*' files.

The livestock development simulations have been repeated 5 times, to simulate at random the chance of death, bareness, still birth etc. in each appropriate category.

The program does not cater for modifications in cattle performance due to changing animal health conditions. It is assumed, optimal veterinary care is provided.

Miscellaneous

For a better understanding of the program the following notes should be born in mind:

* In the simulation of a supplementary feed gift, it should be realized, that the required amount per hectare has to be multiplied by the total area of the grazing unit concerned. The extra feed is added to the produced biomass in the herbaceous layer away from canopy.
* Contrary to general practice, pregnant cows and pregnant cull cows are sold by APSRAMB.
* Lactating cows and cull cow and their respective calves are not sold for the first eight months.
* The APSRAMB output (herd development and sales) is shown yearly for the month of August.

6.4.3.2 Improvement of existing cattle production systems

With the use of APSRAMB, the two main cattle production systems practiced in the study area have been evaluated. Two starting herds were defined to approach an average herd situation for both the village and the cattlepost systems.

In both instances (village and cattlepost) a traditional and an improved scenario have been run for the same initial herd, in order to compare the impact of improved management interventions on the herd development and the financial performance of the production systems. The characteristics related to biomass and management of the traditional and improved village grazing systems are reflected in Table 45, while Table 46 shows the properties of the traditional and improved cattlepost grazing systems.

Due to the low digestibility fraction of the available biomass, it was simulated, that the biomass on offer in the transfer files (the dry matter production of the range, as calculated by the biomass module, see Section 6.4.2.1) consisted of grazing (herbs under and away of canopy) and browse (leaves of lower bush). The intake coefficient of the animals was slightly raised compared to the standard value set for the Tswana breed. Both these measures were taken to simulate, that a small percentage of the herd survived very dry years with low biomass production, under traditional management. This seems legitimate, as it approaches reality, where in times of a severe drought always a few, very strong animals remain alive.

Several management intervention, that are in reach of the concerned cattle owners, have been simulated in the improved scenarios. They are initially aimed at counteracting the drop in herd size, due to starvation during dry year with a low biomass production.

The first additional input consists of supplementary feed (dry matter in the form of hay or stover), given in seasons with a total rainfall < 400mm, which considerably reduced starvation of animals.

Secondly, raised offtake rates, increased the cash returns on the herd. Instead of a large number of animals dying from starvation and a huge loss of capital, some of the invested money was recuperated in cash. The number of surviving animals after a drought is small, whether the offtake rates are high or low. They form, however, the basis for the recovery of the original herd. Lastly, the simulation of a confined breeding season, hence calving under the best circumstances, had a positive impact on the herd development.

Lastly, a controlled breeding season (as opposed to incidental breeding all year) made a positive impact on the herd development in the case of an improved cattlepost herd.

For the sales of cattle from both herds (village and cattlepost situation), it is defined in the management systems, that animals are sold irrespective their condition (live weight), but as soon as they meet the specified age requirement. For the sake of simplicity, sales have been defined to take place in the month of May only. Animals should then be in good shape after a period with enough grazing, in case of a good rainfall season.

Table 45. Characteristics village grazing systems

PRODUCTION SYSTEM	BIOMASS		MANAGEMENT				
	AGGREGATIONS	SUPPLEMENT FEED	LAND		SALES		BREEDING SEASON (months) [4]
			GRAZING AREA (ha) [1]	WALKING DISTANCE (km) [2]	CATEGORY [3]	PERIOD (months) [4]	
ECv *herd.hrd*	grazing area A transfer file: *village.bio*	none	360	14,13,13,14,14,14, 15,16,17,17,17,17	50% cull cows 50% steers 5yr 50% steers 6+yr	5	all year
ECv_i *herd.hrd*	grazing area A transfer file: *vilimsup.bio*	(July 1981/82/83/84/85 86/89/90/92/93): 400 kg/ha DM, digest. 0.5 *suptraim.sup*	360	14,13,13,14,14,14, 15,16,17,17,17,17	100% cull cows 100% steers 4yr 100% steers 5yr 100% steers 6+yr	5	all year

Table 46. Characteristics cattlepost grazing systems

PRODUCTION SYSTEM	BIOMASS		MANAGEMENT				
	AGGREGATIONS	SUPPLEMENT FEED	LAND		SALES		BREEDING SEASON (months) [4]
			GRAZING AREA (ha) [1]	WALKING DISTANCE (km) [2]	CATEGORY [3]	PERIOD (months) [4]	
ECc *herdcatp.hrd*	grazing area B transfer file: *catlpost.bio*	none	4200	11,10,10,11,11,11, 12,13,14,14,14,14	70% cull cows 50% steers 4yr 50% steers 5yr 50% steers 6+yr	5	all year
ECc_i *herdcatp.hrd*	grazing area B transfer file: *catlpsup.bio*	(July 1981/82/83/84/85 86/89/90/92/93): 400 kg/ha DM, digest. 0.5 *catlpsup.sup*	4200	11,10,10,11,11,11, 12,13,14,14,14,14	100% cull cows 100% steers 4yr 100% steers 5yr 100% steers 6+yr	5	2,3,4,5

1 Indicating the proportion of a grazing area (ha) available for a herd of the defined size
2 Daily distance walked (km) for grazing and watering, expressed on a monthly basis from January-December
3 Percentage of animals from given category sold
4 Months: 1 = January, 2 = February, etc.

Extensive grazing of a small cattle herd on communal land around the villages

The traditional small cattle herd kept close to the settlements and watered in the Boteti River, is simulated by production system ECv. The improved situation is reflected by production system ECv_i. For the traditional system, the input biomass consists of an aggregation of the dry matter produced in grazing area A (alluvial and lacustrine land units and 30% of the sandveld), see Table 45. The used biomass transfer file is called *village.bio*. No supplementary feed is given.

In terms of management, the daily walking distance is around 14km during the season with fresh biomass available, increasing to 17km during the dry season. APSRAMB simulates a 5% reduction in forage intake level for each kilometer walked more than 14km/day. Offtake rates are low. It is simulated, that 50% of the cull cows and steers 5+yr are sold in the month of May. Breeding can take place all year. The traditional management characteristics are stored in the *tradunim.man* file.

Improved management interventions are focussed on achieving a higher survival rate during drought years and on obtaining higher cash returns in any given year. These two measures can be simulated by providing supplementary feed of 400 kg dry matter/ha with a digestibility of 0.5 in dry years (rainfall seasons of < 400mm) and increased offtake rates upto 100% of all cull cows and all steers of 4+yr. A supplementary feed file *suptraim.sup* has been aggregated to the naturally available biomass, leading to a transfer file called *vilimsup.bio*. The improved sales parameters are reflected in the improved *tradimpr.man* file.

The initial herd, *herd.hrd*, consists of 27 animals, divided over 12 categories, see Tables 47 and 48, year 1974. This herd is chosen as a standard starting herd for both production systems ECv and ECv_i, reflecting a medium size herd for the average village household. No bull is included in the herd, as most owners do not have one. Conception is left to the chance, that cows meet one of the few bulls in the field at the right time. The livestock module simulates the herd development over the chosen period 1974-1993, see Table 47 and Figure 11 for the herd development and sales (in table and graph format) over time for the production system ECv, and Table 48 and Figure 12 for the comparable results of production system ECv_i.

Observations

* When the biomass produced on a grazing unit drops below the amount of 800 kg/ha (due to drought), the intake by cattle drops (intake threshold); the animals will have to spend more time and energy finding enough dry matter to eat. If the produced biomass drops below 300 kg/ha, cattle dies, due to the struggle to feed (starvation biomass threshold).
* The herd under production system ECv shows a stable development during the 1970s and early 1980s with a total size of 32-33 animals, of which 11-12 are cows and 2 cull cows.
* A delay in reaction of the herd on a drought situation of a year/season is noticeable. The rainy season 1981/1982 was poor and the biomass produced was relatively low. For the production system ECv, the graph in Figure 11 shows a considerable drop in animal numbers during the season 1982/1983.
* Despite the high mortality during the drought of the 1980s, the herd stabilizes at 6-7 animals until 1993. On average 2 cows and a cull cow (potential animals to produce calves and maintain or increase the herd size) stay in the herd during the 1980s.
* Where the sales under the system ECv reached a peak of 3 animals/yr (a cull cow, a steer 5yr and a steer 6+yr) during the late 1970s and the beginning 1980s, the sales drop to zero at the end of the 1980s and the beginning 1990s.
* When supplementary feed is given under production system ECv_i, no extreme mortality occurs and the herd size stabilizes at approximately 21 animals, after the very dry season 1981/1982. The number of cows drops only slightly over the total simulated period and is around 9-10.
* Due to the increased sales, the total herd size of the system ECV_i is somewhat smaller in the 1970s as compared to the production system ECv. Although over time the sales fluctuate a bit, approximately 2-3 animals are sold per year over the entire simulated period. Sales concentrate as specified on cull cows and steers 4yr, see Figure 12.

Table 47. Herd development and sales of traditional village grazing system (ECv)

HERD DEVELOPMENT

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Heifer calf	3	3	2	2	2	2	4	2	3		1	1		1		1		1	1	1
Heifer 1yr	2	3	2	2	2	2	1	4	2			1					1		1	
Heifer 2yr	2	2	3	1	1	1	1		2				1					1		
Cow	9	10	10	12	12	12	11	11	11	4	4	3	2	2	2	2	2	1	2	2
Cull cow	1	2	2	2	2	2	2	2	1		1	1	1	1	1	1	1	1	1	1
Bull calf	3	3	2	2	2	2	3	2	3	1			1				1			
Steer 1yr	1	3	3	1	2	2	2	3	1		1			1				1		
Steer 2yr	2	1	3	3	1	2	2	1	3						1					
Steer 3yr	1	2	1	3	3	1	2	2	1							1				
Steer 4yr	2	1	2	1	3	3	1	2	2								1			
Steer 5yr	1	2	1	2	1	2	2	1	1	1								1		
Steer 6+yr		1	2	2	2	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
TOTAL	27	33	33	33	33	32	32	32	31	7	8	7	6	6	5	6	7	7	6	5

SALES

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Cull cow			1		1	1	1	1	1				1			1				
Steer 4yr																				
Steer 5yr			1		1	1	1	1		1										
Steer 6+yr				1	1	1	1	1	1	1	1	1								
TOTAL	0	0	2	1	3	3	3	3	2	2	1	1	1	0	0	1	0	0	0	0

Figure 11. Herd size, number of cows and animals sold of traditional village grazing system

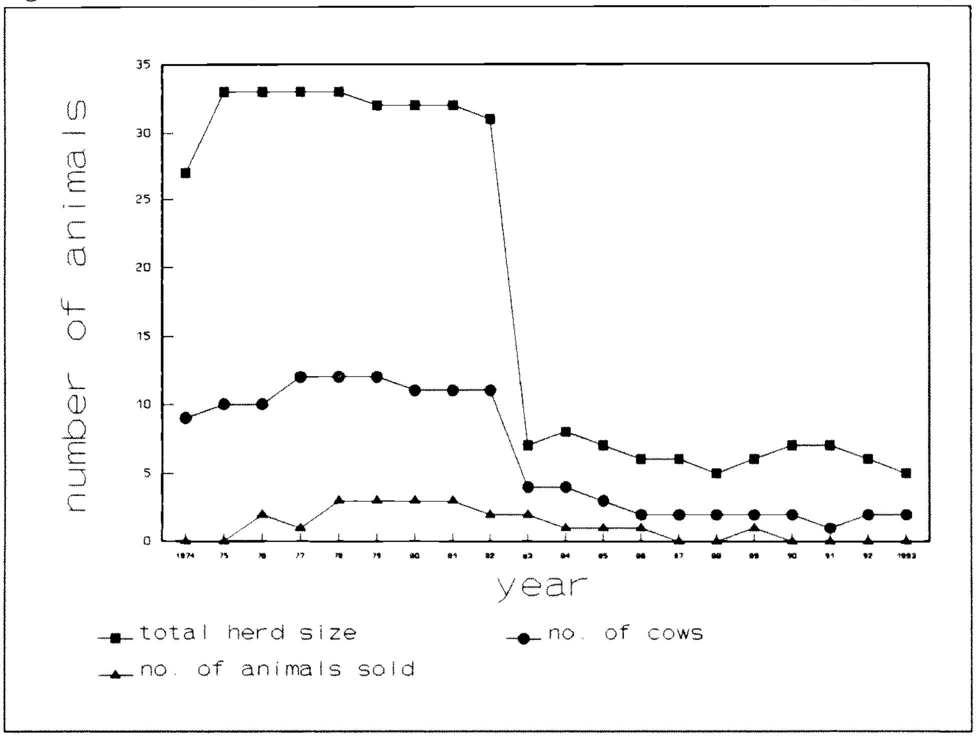


Table 48. **Herd development and sales of improved village grazing system (ECv_I)**

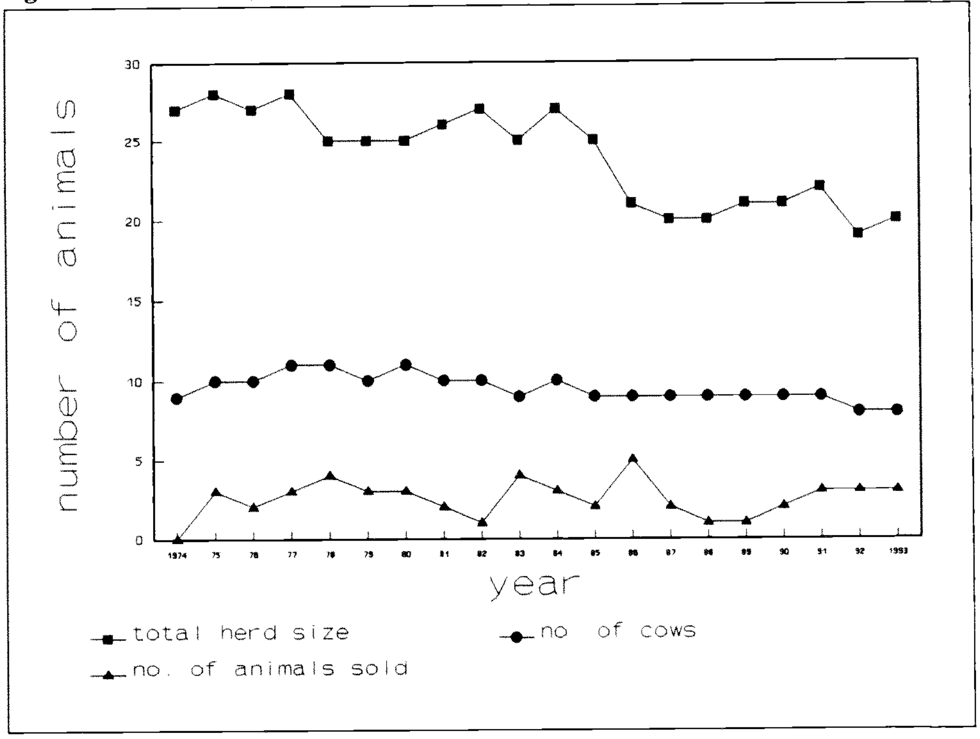
HERD DEVELOPMENT

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Heifer calf	3	2	2	3	2	3	3	3	2	2	3	2	2	1	2	1	2	2	1	2
Heifer 1yr	2	2	1	2	2	1	2	2	3	2	2	2	1	2	1	1	1	2	2	1
Heifer 2yr	2	2	2	1	1	1		1	1	2	2	2	1		1	1	1	1	1	2
Cow	9	10	10	11	11	10	11	10	10	9	10	9	9	9	9	9	9	9	8	8
Cull cow	1	2	1	1	1	1	1	1	1	1	2	2	1							
Bull calf	3	3	2	1	2	3	3	3	2	2	2	2	2	2	2	3	1	2	1	2
Steer 1yr	1	3	3	2	1	2	3	2	2	2	2	1	2	2	2	2	3	1	2	1
Steer 2yr	2	1	3	3	2	1	1	3	2	2	2	2	1	2	1	2	2	3	1	2
Steer 3yr	1	2	1	3	3	2	1	1	3	2	2	2	2	1	2	1	2	2	3	1
Steer 4yr	2	1	2	1		1			1	1		1		1		1				1
Steer 5yr	1																			
Steer 6+yr																				
TOTAL	27	28	27	28	25	25	25	26	27	25	27	25	21	20	20	21	21	22	19	20

SALES

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Cull cow			1	1	1	1	1	1		1	1	1	3	1				1	1	1
Steer 4yr		2	1	2	3	2	2	1	1	3	2	1	2	1	1	1	2	2	2	2
Steer 5yr		1																		
Steer 6+yr																				
TOTAL	0	3	2	3	4	3	3	2	1	4	3	2	5	2	1	1	2	3	3	3

Figure 12. **Herd size, number of cows and animals sold of improved village grazing system**



Extensive grazing of a medium sized herd around a cattlepost on communal land

The traditional cattlepost situated in the sandveld (watering from a wellpoint/borehole at the cattlepost) is simulated by production system ECc. The improved cattlepost system is reflected by production system ECc_i. The traditional system has an input biomass consisting of 70% of an aggregation of the dry matter produced in grazing area B (the sandveld), see Table 46. The biomass transfer file used, is called *catlpost.bio*. No supplementary feed is given.

In terms of management, the daily walking distance is around 11km during the wet season and shortly after, increasing to 14km during the dry season. As animals are watered at the cattlepost, they roam around it in search for food. Offtake rates are somewhat higher than in the traditional village grazing system ECv, represented by the sales of 70% of the cull cows and 50% of the steers 4+yr. Sales take place in the month of May, when animals reach their peak condition and breeding happens all year. The parameters belonging to the traditional cattlepost production system ECc are stored in the *catlp.man* file.

Improved management interventions concern supplementary feed of 400 kg dry matter/ha with a digestibility fraction of 0.5, increased offtake rates upto 100% of all cull cows and all steers 4+yr and a concentrated breeding season from February-May. The rest of the year bulls are kept separated from the herd. This intervention makes cows calve during the months of November-February, the time of the year with the best grazing. A supplementary feed file *catlpsup.sup* has been combined with the naturally available grazing into an aggregated transfer file called *catlpsup.bio*. The improved sales parameters and the controlled breeding season are defined in the *catlpimp.man* file.

The starting herd, *herdcatp.hrd*, contains 120 animals, belonging to 12 categories, see Tables 49 and 50, year 1974. This herd reflects an average cattlepost herd and serves for both production systems ECc and ECc_i. No bull is included in the herd definition, as bulls fall under one of the categories of steers 4, 5, 6+yr. The herd development and sales are evaluated over the chosen 20 year period 1974-1993, see Table 49 and Figure 13 for the results for the traditional cattlepost production system ECc, and Table 50 and Figure 14 for the improved cattlepost situation ECc_i, respectively.

Observations

* After an initial increase in total herd size from 120 animals, the herd under the traditional cattlepost production system ECc stabilizes at 144 animals end 1970s beginning 1980s, of which approximately 53-55 are cows and 6-7 cull cows. The impact of the drought year 1981/1982 is, like in the traditional village production system ECv, clearly visible in a drop in numbers in 1983, see Figure 13. After the sudden plunge of approximately 40 animals in 1983, the herd diminishes in size gradually until 1993. The end herd consists of 62 animals, half the size of the strating herd in 1974. The end herd contains 24 cows and 1 cull cow in 1993.
* The sales under the ECc system remain more or less constant over the evaluated period and amount 9-11 animals per year, with a peak up to 15 animals in 1978. In most years, 2-4 animals per specified category were sold: cull cows and steers 4yr, 5yr and 6+yrs.
* The herd of the improved cattlepost production system ECc_i develops prosperously. The provision of supplementary feed during the dry years prevents the herd from decreasing in size. This effect is probably enhanced by the regulation of the breeding season. This last factor will reduce calf mortality rates considerably and gives the herd the chance to expand in size. The starting herd of 120 cows, more than doubled; the end herd consisted of 294 animals in 1993, see Figure 14. The number of cows in the herd tripled from 43 in 1974 to 130 in 1993. The number of cull cows remained between 4-8; this concerns lactating cull cows (which can not be sold), as the specification for sales was 100% of all cull cows.
* The increased offtake rates of the system ECc_i, as compared to the traditional cattlepost system ECc, show a 100% increase in sales over the evaluated period. The yearly amount of sold cull cows rises from 4 to 8, while the sales of steers 4yr increases from 9 to 16 per year.

Table 49. Herd development and sales of traditional cattlepost grazing system (ECc)

HERD DEVELOPMENT

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Heifer calf	13	11	10	10	12	12	11	13	13	10	11	9	8	7	7	5	7	5	6	5
Heifer 1yr	8	12	10	9	9	11	11	9	12	2	8	9	7	7	6	6	4	5	4	3
Heifer 2yr	8	7	12	8	7	6	6	6	5			4	5	3	5	4	4	2	3	2
Cow	43	44	47	53	54	55	54	55	55	50	44	38	32	32	29	30	27	25	22	24
Cull cow	4	8	6	6	7	7	7	7	7	4	7	8	7	5	5	4	5	4	4	1
Bull calf	15	14	10	11	10	12	13	11	9	8	12	10	9	6	8	6	6	5	7	6
Steer 1yr	4	14	13	10	10	9	11	12	10	3	7	11	8	9	4	7	5	5	5	5
Steer 2yr	8	4	14	12	10	9	8	10	12	1	2	6	11	7	9	4	7	5	4	4
Steer 3yr	4	8	4	14	11	10	9	8	9	11	1	1	6	10	7	9	4	7	5	4
Steer 4yr	8	4	8	4	9	7	7	7	7	8	8	1	1	5	8	6	6	4	5	4
Steer 5yr	4	4	2	4		4	3	3	2	2	3	4		1	1	3	2	3	1	2
Steer 6+yr	1	3	4	3	4	2	3	3	3	3	2	3	4	2	2	2	3	2	3	2
TOTAL	120	133	140	144	143	144	143	144	144	102	105	104	98	94	91	86	80	72	69	62

SALES

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Cull cow			4	3	3	3	3	4	4	2	2	4	9	6	4	4	3	5	3	2
Steer 4yr		4	2	4	9	4	5	3	3	4	4		1	1	4	3	4	1	3	2
Steer 5yr		2	2	1	2	4	2	3	3	3	3	4	1		1	3	2	2	1	2
Steer 6+yr			1	2	1	2	3	2	3	2	2	2	2	2	1	1	2	2	2	2
TOTAL	0	6	9	10	15	13	13	12	13	11	11	10	13	9	10	11	11	10	9	8

Figure 13. Herd size, number of cows and animals sold of traditional cattlepost grazing system

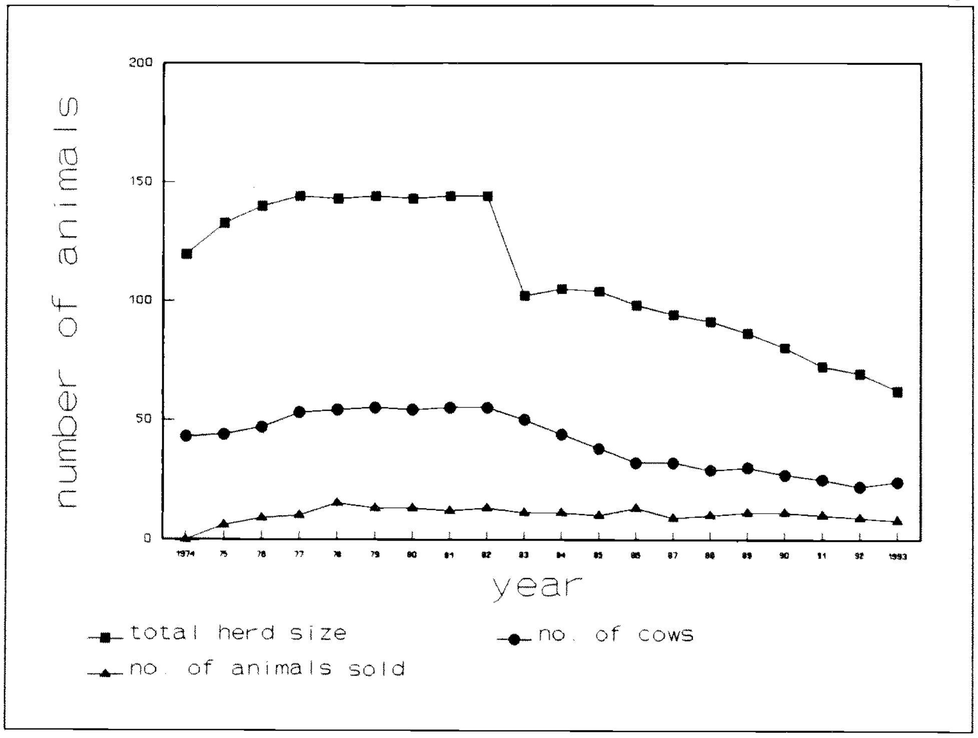


Table 50. Herd development and sales of improved cattlepost grazing system (ECc_i)

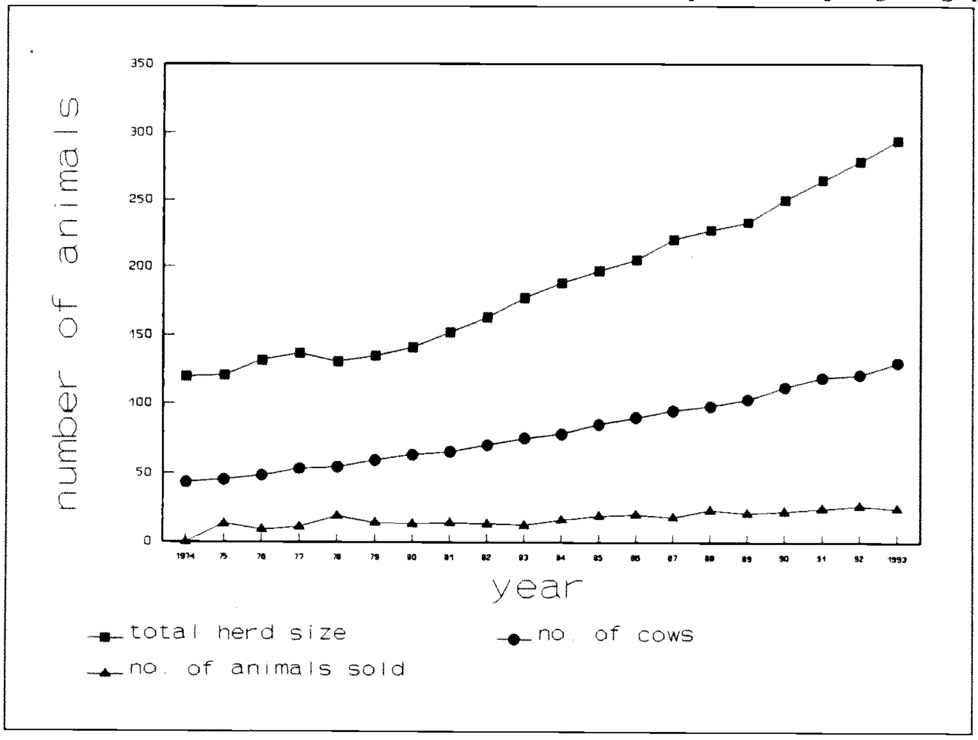
HERD DEVELOPMENT

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Heifer calf	13	8	14	11	9	12	12	14	15	16	15	17	17	21	19	18	25	23	25	22
Heifer 1yr	8	12	8	13	10	9	11	11	14	14	15	14	16	16	19	18	17	24	21	24
Heifer 2yr	8	8	12	7	12	10	8	11	11	13	13	15	14	16	16	18	18	16	23	20
Cow	43	45	48	53	54	59	63	65	70	75	78	85	90	95	98	103	112	119	121	130
Cull cow	4	8	6	6	6	5	5	5	6	7	8	7	4	3	4	2	3	5	4	6
Bull calf	15	10	10	11	11	10	12	15	13	15	19	16	19	20	20	21	22	24	26	27
Steer 1yr	4	14	10	10	10	11	10	12	14	12	14	18	15	18	19	18	18	21	22	24
Steer 2yr	8	4	13	10	9	10	10	9	11	14	12	14	17	14	18	18	17	17	20	21
Steer 3yr	4	8	4	13	10	9	10	10	9	11	14	11	13	17	14	17	18	16	17	20
Steer 4yr	8	4	7	3																
Steer 5yr	4																			
Steer 6+yr	1																			
TOTAL	120	121	132	137	131	135	141	152	163	177	186	197	205	220	227	233	250	265	279	294

SALES

CATEGORY	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Cull cow			5	4	3	5	4	4	3	3	5	5	9	5	7	8	5	6	10	8
Steer 4yr		8	4	7	16	9	9	10	10	9	11	14	11	13	16	13	17	18	16	16
Steer 5yr		4																		
Steer 6+yr		1																		
TOTAL	0	13	9	11	19	14	13	14	13	12	16	19	20	18	23	21	22	24	26	24

Figure 14. Herd size, number of cows and animals sold of improved cattlepost grazing system



For the financial performance of the simulated production systems, reference is made to Section 6.4.5. No evaluation has been done of the production system EGv, extensive grazing of a flock of goats on communal land around the villages.

6.4.4 Mitigation of additional limiting factors

The simulations carried out in Section 6.4.3.2 assume optimal conditions. Several management interventions are not taken care of, but could be considered.

Animal health care

Improved animal health care will improve the overall condition of animals, increase calving percentages and drop mortality rates. Apart from the free, compulsory inoculations provided by the Veterinary Department, a sum should be budgeted for to cater for the improved animal health services.

By proper herding (by a herd boy) and consequent kraaling of animals during the night (near the settlement or the cattlepost), predation can be minimized, and thus the loss of animals due to kills by hyenas and other predators.

Improved management

Not simulated with the help of APSRAMB in Section 6.4.3.2 were improvements like the reduction of the daily walking distance, by providing water in the grazing area, through water reticulation, water catchment tanks or boreholes, and different sales options (other animal categories) and sales period(s).

In order to improve the herd quality and to regulate breeding, Artificial Insemination facilities should be improved by drilling a borehole in the AI Camp at Makalamabedi. As soon as the water problem has been solved, the AI Camp can be reopened and services resumed.

Controlled grazing and improved feed

Also worthwhile evaluating with APSRAMB would be a reduction of the grazing area in the management file, in order to simulate the herd development on a smaller grazing unit. This would approach a situation of controlled grazing, by setting aside a portion of the initial grazing area by means of a drift fence or paddock fences. In the unaccessible area, biomass can be left for grazing later in the season or hay can be cut. This might decrease starvation of cattle in dry periods and reduce the costs of the import of supplementary feed. Transport costs will be very high, as the nearest place to buy supplementary feed from is Pandamatenga.

The effect of a supplementary feed gift to selected categories of animals (e.g. pregnant and lactating cows and heifers or fattening of animals just before the date of sales) should be assessed as well.

The creation of improved pastures in the Chanoga AEA is difficult, seen the unreliable surface water situation. When a constant water sources can be developed (borehole), this option might further be explored.

Soils in the study area are rather favourable for the growth of leguminous fodder crops. When depending on the rains, the growing season is limited. A reliable water source should preferably be assured. Farmers in the study area do not have a great tradition in growing fodder crops. Some assistance from the extension service might be required. The same accounts for the production of enriched crop residues. Labour and cash shortages will probably not favor the introduction of this improvement. It is easier to let livestock in the fields to eat stover after the harvest.

6.4.5 Financial analysis of cattle production systems evaluated with APSRAMB

As the APSRAMB program has not yet been equipped with a module for financial analyses, the assessment will be kept very simple. From each production system evaluated in Section 6.4.3.2, the value of the salvage herd (herd composition in the year 1993) plus the income from sales (over the total period 1974-1993) has been compared to the value of the starting herd (herd composition in the year 1974). This gives a gross profit or loss figure, which forms a relative indication of the performance of the herd under the set management conditions.

Costs of inputs like implements, veterinary care, supplementary feed and fencing have not been included in the calculations. Hence no gross margin analysis of the simulated production systems was conducted. In a later stage a module for a gross margin analysis, and a discounted cash flow analysis, leading to parameters as net present value and internal rate of return will be available.

It should be noted, that the value of animals is kept the same for the 1974 and the 1993 situation. This is an oversimplification, but it simulates the increase in value through interest of money earned from sales and saved in a bank account.

In order to value sold animals, a grading exercise was carried out. Based on age and weight, all sold animals were graded according to the BMC grading system, see Table 51 with the used criteria per animal category.

Table 51. Criteria for grading of sold cattle

CATEGORY	AGE (months)	WEIGHT (kg)	GRADE	KILL OUT %
cull cow	≥ 144	no restriction	4	50
steer 4yr	48-60	340-400	1	54
steer 5yr	60-72	≥ 350	1	54
	60-72	300-350	2	52
steer 6+yr	72-120	≥ 350	2	52
	72-120	300-350	3	51
	120-150	325-350	3	52
	150-170	275-325	4	50
	≥ 170	250-275	4	50

With help of the kill out % (the fraction of meat remaining from the animal after deboning), the cold dressed weight can be calculated (original weight * kill out %). The value of a slaughtered animal is calculated by multiplying the cold dressed weight by the price/100kg, according the BMC price structure by grade for the Francistown Abattoir 1995 (see Section 4.4.5).

The financial performance of the 4 evaluated production systems is shown in Table 52.

Table 52. Simplified financial performance of the evaluated production systems (figures in Pula)

PRODUCTION SYSTEM	START HERD VALUE	END HERD VALUE	DIFFERENCE	SALES	RESULT
ECv	21,000	3970	- 17,030	14,250	- 2780
ECv_i	21,000	16,020	- 4980	38,204	33,224
ECc	93,600	48,430	- 45,170	143,386	98,216
ECc_i	93,600	239,480	145,880	250,350	396,230

The final result for each production system has been derived at by calculating the DIFFERENCE between the end herd value and the start herd value. Subsequently, the income through SALES has been added to the DIFFERENCE, leading to the RESULT.

Observations

* It should be noted, that the results of the above financial analysis should not be taken as absolute profit or loss figures. However, the results have a relative value, indicating the performance of the evaluated production systems.
* The traditional village grazing system ECv ended with a very small salvage herd at the end of the simulated period. This caused a negative difference compared with the start herd value. Sales were not extremely high, but almost neutralized the negative balance, leading to a small gross loss.
* Despite the provision of supplementary feed, but more likely due to an increase in sales, the end herd under the improved village grazing production system ECv_i turned out slightly smaller than the starting herd. This resulted in a small negative difference in monetary terms between the end and the starting herd. The difference, however is much smaller than in the case of the traditional village grazing system ECv. As the offtake rates were raised as compared to the ECv system, the total sales figure for the improved village grazing system ECv_i is nearly three times as high as for the traditional situation. This made the final result into a gross profit.
* The traditional cattlepost production system ECc ended with a salvage herd of half the size of the initial herd. A large negative difference resulted. But as the sales were constantly at an intermediate level, the end result was a medium gross profit. The practiced management system seems a good financial way to curb the negative effects of a drought.
* Due to the controlled breeding season, the herd of the improved cattlepost production system ECc_i ended up much larger than the starting herd, and than the end herd of the traditional cattle post system ECc, causing a large positive difference in value. As the sales increased towards the end of the simulation period, due to the increasing herd, the sales figure is high and the final result is a hugh gross profit. It has to stressed again, that no inputs are taken into account. It is recommended to increase the sales and to look for a sustainable herd optimum.

6.4.6 Alternative production systems

With regard to diversification, alternative animal based production systems can be thought of. One example is worked out below, consisting of two productions systems, that can either be carried out separately or in conjunction, see Table 53.

The first production system is the rearing of ducks. Based on two breeding females and one drake, a conservative amount of 15 ducklings is raised per hatching. The average hatching cycle is 20 weeks, leading to 2.5 hatchings/yr. It is assumed, that the breeding animals are slaughtered and sold after one year. This low input production system results in a gross margin of P 340.50/yr. The main requirements are water and some labour for feeding and watering the animals and cleaning the pen. When the assets are renewed every 5 years, the net farm income amounts P 288.50/yr.

The second production system is the keeping of chickens for egg production. The example is based on 10 layers, with a conservative laying capacity of 70% per day. The layers are slaughtered and sold after one year. The gross margin of this production system is P 700.00/yr. Some farm labour is required for feeding, watering and pen cleaning. Based on a replacement of the assets every 5 years, the net farm income is P 652.00/yr.

When these two production systems are combined in one operation, the gross margins can be added and the total amounts P 1040.50/yr. As only one single pen is needed the combined net farm income is P 970.50/yr.

The produce can be marketed in the settlements in the study area amongst neighbours or in Maun. Duck meat is in great demand in Maun, while the supply is limited. From the above figures it can be concluded, that small scale enterprises based on duck rearing and/or chicken egg production are well in reach of small farmers and can contribute considerably to the household income. Prerequisites are a reliable water source and access to starting capital.

Table 53. Evaluation of a duck and chicken pen

FINANCIAL PLAN DUCK AND CHICKEN PEN (1 year) pen size 100 m2

REQUIREMENTS

DUCKS

water – 0.5 liter/adult bird/day	145 l/month	1740 l/year
pond for reproduction		
household organic waste (optional)		

CHICKENS

water – 0.5 liter/adult bird/day	105 l/month	1260 l/year
household organic waste (optional)		

VALUE OF OUTPUT

DUCKS

PRODUCE	QUANTITY	UNIT VALUE (Pula)	TOTAL VALUE (Pula)
7 weeks old ducks (2.5 hatchings/year)	15	15	562.50
adult breeding ducks	3	15	45.00
		TOTAL	**607.50**

CHICKENS

PRODUCE	QUANTITY	UNIT VALUE (Pula)	TOTAL VALUE (Pula)
eggs (70% laying/day)	2555	0.35	894.25
chickens	10	12.50	125.00
		TOTAL	**1019.25**

VARIABLE COSTS

DUCKS

ITEM	QUANTITY	UNIT PRICE (Pula)	TOTAL (Pula)
breeding ducks	3	15	45.00
feed (mash) for 3 breeding ducks (kg)	75	1.11	83.25
feed (mash) for 37.5 chicks (kg)	125	1.11	138.75
		TOTAL	**267.00**

CHICKENS

ITEM	QUANTITY	UNIT PRICE (Pula)	TOTAL (Pula)
layers	10	12.50	125.00
feed (kg mash)	175	1.11	194.25
		TOTAL	**319.25**

FIXED COSTS

DUCKS

ITEM	QUANTITY	UNIT PRICE (Pula)	TOTAL (Pula)
perimeter fence	40 m	150.00	150.00
shelter	1	50.00	50.00
bag of cement for a pond	1	20.00	20.00
water tray	2	10.00	20.00
food tray	2	10.00	20.00
		TOTAL	**260.00**

CHICKENS

ITEM	QUANTITY	UNIT PRICE (Pula)	TOTAL (Pula)
perimeter fence	40 m	150.00	150.00
shelter	1	50.00	50.00
water bottle	2	10.00	20.00
food tray	2	10.00	20.00
		TOTAL	**240.00**

GROSS MARGIN

DUCKS

Value of produce – variable costs = Gross margin: **P 340.50/yr**

CHICKENS

Value of produce – variable costs = Gross margin: **P 700.00/yr**

DUCKS + CHICKENS COMBINED

Value of produce – variable costs = Gross margin: **P 1040.50/yr**

NET FARM INCOME

DUCKS

Gross margin – 20% fixed costs = Net farm income: **P 288.50/yr**

CHICKENS

Gross margin – 20% fixed costs = Net farm income: **P 652.00/yr**

DUCKS + CHICKENS COMBINED

Gross margin – 20% fixed costs = Net farm income: **P 970.50/yr**
(only 1 perimeter fence included)

* Value of output based on Maun market prices
* Cost of breeding ducks and layers based on Maun market prices
* Feed prices from Livestock Advisory Centre
* Fence costs based on FAP guidelines; other fixed costs based on Maun market prices

** Net farm income based on 20% of fixed costs, assuming a replacement interval of 5 years

6.5 Evaluation of veld product systems

From all veld products utilized in the study area, 6 are most frequently collected or have a potential to generate a cash income. See Figure 5 in Section 3.6.3 for small scale distribution maps of each species. Table 54 shows the main management and financial characteristics of the production systems involving the collection and sales of *Grewia* berries, lethaka reeds, mopane poles and fuelwood, motsintsila berries, rothwe leaves and thatching grass.

The veld products are abundant on the mentioned land units in most years. If harvested in a sustainable way, all six veld products have a high production potential. The yield figures and the unit values given in Table 54 are based on the farm survey. The mopane trees are not systematically harvested at present. The value of the standing crop and the sustainable harvest are based on average biomass production figures generated by APSRAMB.

A brief discussion of the six production systems follows below.

Grewia **berries**

The mogwana berries are harvested during the months May and June, while the moretlwa berries are collected in December and January. The two shrubs are very common in the study area. Harvest of the berries takes place on a relatively small scale, does not affect the reproduction of the shrubs, and is hence sustainable. Both berries are mainly used for beer brewing. The khadi is traditionally used as payment in kind for "hired" labour, for bartering or just sold per cup to supplement the cash family income. No information was gathered on the quantities harvested and the conversion factor into beer. A mug of khadi is sold for Pula 0.50.

Lethaka

Reed cutting is traditionally done from April-June. One person (mainly women) cuts 5 bundles with a diameter of 40cm a day. One bundle is sold for P 5.00 in Chanoga. When one person is engaged in reed cutting for 5 days a week during 10 weeks, she can gather 250 bundles with a total market value of P 1250.

IUCN (1992) estimates the market value of standing crop at Pula 10,000/ha. Based on APSRAMB, the average yearly biomass production for vegetation unit V1 consisting of *Phragmites australis* is 5800 kg/ha, which can be considered as the yearly sustainable harvest. This sustainable harvest has a market value of P 2900/ha, assuming one bundle weighs approximately 10 kg.

The vegetation unit V1 covers 259 ha. Many patches of lethaka, however, have been burnt down the past few years. This damage affects approximately 80% of the vegetation unit and was probably enhanced by the not flowing of the Boteti River the past 4 seasons. No farmer could explain whom burnt the reeds and for what reason. It is suspected, it has something to do with the groundwater levels in wells in the Boteti River bed. Maybe it is thought, that lethaka extracts too much water from the ground for its growth, while water is badly needed for domestic use and to water cattle and smallstock.

As lethaka, when well managed, is a very valuable and renewable resource, it asks for a greater awareness amongst the caretakers of the resource and possibly an organized exploitation.

Mopane

Mopane logging is not practiced in a structural way. The occasional pole is harvested to be used as rafter, fence pole or for fuelwood. Depending the straightness of the pole and the use, an average market value of P 50/m^3 is obtained. Vegetation unit V10 comprises full grown mopane trees. Based on an approximate density of 225 trees/ha, and a volume of the stem and the main branches of 1 m^3 per tree, the market value of the mopane stand in unit V10 is P 11,250/ha.

Table 54. Characteristics of veld product systems

MANAGEMENT AND FINANCIAL PARAMETERS	PRODUCTION SYSTEMS					
	GREWIA	LETHAKA	MOPANE	MOTSINTSILA	ROTHWE	THATCHING GRASS
LAND UNIT	AS2, SV1, SV2	AS1	SV1	AS1, AS2	AS2	LS1, SV1, SV2
HARVEST MODE	berries	bundles	logs	berries	bags of leaves	bundles
END PRODUCT	beer	reeds	poles	sweets	boilt leaves	roofing material
USE	beverage	fencing	building, fuelwood	sweets	vegetable relish	building
YIELD	?	5 bundles/day	not harvested now	?	30 kg fresh leaves/day	?
UNIT VALUE	P 0.50/mug	P 5/bundle	P 50/m3	P 1/cup	P 1/cup boilt leaves	P 1/bundle
CONVERSION FACTOR	?	1 bundle = 10 kg	1 m3 = 1200 kg	?	?	1 bundle = 1 kg
VALUE STANDING CROP	?	P 10,000/ha	P 11,250/ha	?	?	P 3000/ha
SUSTAINABLE HARVEST	?	5800 kg/ha/yr	700 kg/ha/yr	?	?	2400 kg/ha/yr
VALUE SUST. HARVEST	?	P 2900/ha/yr	P 30/ha/yr	?	?	P 2400/ha/yr

The air dry weight of 1 m^3 of mopane logs equals 1200 kg (Roodt, 1993). APSRAMB simulates an average yearly biomass increment of 700 kg/ha (stems of trees, upper and lower bush), which corresponds to 0.6 m^3. This sustainable harvest has a market value of P 30/ha/yr.

The vegetation unit V10 has an extend of 2710 ha. Although the return per hectare is not so high, there seems to be a justification for the sustainable exploitation of this resource, considering the extent of the vegetation unit. The unit is located in the northwestern corner of the AEA, and has an relatively easy access to Maun, 25 km to the west.

It is suggested that exploitation is undertaken by the local community (through the VDC), and that the sustainable harvesting is adequately controlled by the Forestry Division.

Motsintsila

Motsintsila berries occur in the vegetation unit V11, the riverine "forest" along the Boteti River. No yield figures are known. The berries are dried and eaten as sweets. A cup is sold for P 1.00 at the informal market in Maun.

Rothwe

Rothwe is mostly growing from December-March, during the rainy season. The fresh leaves are picked then, before flowering. Collecting rothwe leaves is a typical female occupation; 1 woman gathers a 30 kg bag/day. This is boiled, which reduces the initial weight to 12.5 kg (ratio 2.4). One cup of the cooked vegetable relish is sold for P 1.00. No information was collected on the harvestable amount per hectare. This wild spinach occurs abundantly in vegetation unit V9. It can be sustainably harvested as only the larger leaves of the plant are picked, which does not affect the reproduction of the species.

Thatching grass

Thatching grass is mainly found in vegetation unit V4 on the sandveld and collected and sold locally. A bundle with an approximate weight of 1 kg has a market value of P 1.00. The dry matter weight of the standing grass biomass is estimated at 3000 kg/ha, corresponding with a market value of P 3000/ha. The average yearly herbaceous biomass production on the land units SV1 and SV2 is calculated by APSRAMB at 2400 kg/ha. As the harvest does not affect the regrowth of the plants, grass can be gathered in a sustainable way at a market value of P 2400/ha. Competition for this resource comes from grazing livestock and scarce wildlife species.

Fuelwood

Wijesuria *et al.* (1995) mentions a fuelwood requirement of 1,7 tonnes dry biomass per capita per year for the Moroka AEA. Based on Roodt (1993) an average dry matter weight of the occurring woody species in the survey area of 900 kg/m^3 is assumed. The yearly fuelwood need concurs then with 1.9 m^3/person.

APSRAMB calculates an average yearly increment of dry matter in the form of stems of trees, upper and lower bush of 48,300 tonnes, which corresponds with an increment of 53,600 m^3/yr for the entire study area. This production of woody biomass could sustainably provide fuelwood to 28,200 people on a yearly basis. As the population of the Chanoga AEA was estimated at 1201 persons in 1994, their total needs of 2280 m^3 are ample met. The population increase of 2.6% per year leads to a total projected population of 1513 people in the year 2004. Their requirements of 2875 m^3 will also be fulfilled, and no scarceness of this resource is foreseen in the near future.

A more precise (species specific) study of availability of fuelwood in concentric rings with radii of 5 and 10 km around settlements can be carried out with advanced GIS techniques.

6.6 Evaluation of wildlife utilization

As mentioned in Section 3.7.3, the Chanoga AEA forms part of the Controlled Hunting Area NG35. This area is designated for citizen hunting. According to Rodgers (1991) citizen hunting is a form of consumptive wildlife based land use, which can be classified either as commercial extensive production systems in case of trophy hunting or as subsistence/recreational production systems. Table 55 below shows the species, that could be hunted, their quota, the license fees per animal and the total revenue collected by the Department of Wildlife and National Parks (DWNP) for the 1995 hunting season. The quota and fees remained the same for the 1996 hunting season.

The total amount of revenue collected by the government through the sales of citizen single game license fees was Pula 526.75, being 30% of the potential. If all quota would have been exhausted, the total revenue would have amounted Pula 1741.00. NG35 has an extent of approximately 4000 km^2. The financial return per km^2 is extremely low and amounts Pula 0.13. With the present quota and fees per animal the potential financial return could have been Pula 0.44 per km^2.

In order to make wildlife utilization as a land use options more compatible with other uses in terms of financial return per unit area, the license fees should be drastically increased. The value of the produce (mainly meat and skins are sold) for the citizen hunters was not accounted for in the above equation of the financial return per km^2.

Alternative ways of wildlife utilization like tourist hunting and a combination of wildlife ranching and cattle rearing in NG35 can be further studied.

Table 55. Controlled Hunting Area NG35 summary single game licenses

SPECIES	QUOTA	QUOTA SOLD	FEE per ANIMAL (pula)	FEE TOTAL (pula)
Duiker	55	31	0.25	7.75
Impala	67	19	1.00	19.00
Kudu	54	30	5.00	150.00
Ostrich	13	6	10.00	60.00
Reedbuck	9	2	1.00	2.00
Sable	1	1	100.00	100.00
Steenbok	82	36	0.25	9.00
Tsessebe	22	3	50.00	150.00
Warthog	19	12	0.25	3.00
Wildebeest	2	2	3.00	6.00
Zebra	1	1	20.00	20.00
			TOTAL REVENUE COLLECTED	**526.75**

source: DWNP Hunting Report 1995 (MCI, 1996).

7. CONCLUSIONS AND RECOMMENDATIONS

The main objective of this agricultural land use plan is to propose measures for the improvement of the existing production systems and to recommend new small scale (agriculture related) income generating activities. Seen in this light, the outcome of the physical and financial evaluations carried out in Chapter 6 will stand alone. The population pressure in the Chanoga AEA is modest and consequently the pressure on land is relatively low and no major land use conflicts occur.

As the entire study area is under some form of intensive or extensive use, and no land use zoning was required, it seems unnecessary to compare the performance and social acceptability of all production systems for all land units. By the same token, the proposed improvements are to support a sustainable production and hence no separate environmental impact assessment is required.

Instead, it is tried in this chapter to formulate recommendations and proposals targeted to groups of farmers with specific available resources. However, as interest and motivation to change are important, the basket of choices is open for all potential land users.

7.1 Improved production systems and proposals for small scale projects

7.1.1 Improved rainfed arable farming

7.1.1.1 Toolkit of extension messages for specific farmer groups

The farmer groups, to which recommendations are targeted, are discussed in the Sections 4.4.2 and 4.4.3.6. No extension advice regarding rainfed cropping is formulated for farmer group R2, as it concerns a group of cattle rearers.

Table 56 forms a comprehensive toolkit with extension recommendations for the improvement of rainfed arable farming. It deals with the 5 crops simulated by the CYSLAMB program (maize, sorghum, millet, cowpea and groundnut), two sets of land units (the depressions with slightly clay richer subsoils AS3, LS2, SV2 and the more elevated parts of the landscape with sandy soils throughout AS2, LS1, SV1) and various management scenarios. The toolkit matrix should be read in conjunction with the Sections 5.1.2, 6.1.1, 6.1.2, 6.1.3, 6.1.4 and 6.3.3 of this report.

Notes indicated by *) in Table 56 are listed on the pages following the table and are numbered according the codes of the corresponding Activity in the table. Table 57 shows a summary of the most important recommendations per farmer group. At the end of this section a recap of the main recommendations per farmer group is given.

The ratings in Table 56 of suitability and relevance of a specific recommendation to each farmer group is, somewhat subjectively, based on the following criteria:

1. labour availability
2. draught power availability
3. access to cash for minor land improvements
4. commitment for change.

Four rating classes are used and defined as follows:

- \+ + very suitable recommendation for farmer group concerned
- \+ suitable recommendation for farmer group concerned
- ± marginally suitable recommendation for farmer group concerned
- \- probably not feasible for members of the farmer group concerned.

Table 56. **Toolkit of recommendations for improvement of rainfed arable farming**

RECOMMENDATION	ACTIVITY	SECTION of REPORT	FARMER GROUP				
			P1	P2	W1	W2	R1
IMPROVED SOIL MANAGEMENT							
1. Improvement of topsoil organic matter content	a) use of kraal manure	5.1.2.1	±	±	+	+	+
	b) ploughing in of crop residue	5.1.2.1	±	+	+	+	+
	c) agroforestry and mulching	5.1.2.1, 6.3.3	-	-	±	+	+ +
2. Improvement of topsoil nutrient status	a) as 1a) and 1b) above						
	b) use of inorganic fertilizer (including maintenance dose)	6.1.1.3, 6.1.4.1	-	-	+	+	+ +
3. Establishment of wind erosion control measures	a) wind breaks/agroforestry	6.3.3	-	-	±	+	+ +
IMPROVED LAND MANAGEMENT							
4. Cultivation on better soils	a) use slopes of depressions (land units AS3, LS2, SV2) or higher, sandy parts (land units AS2, LS1, SV1) *)	5.1.2.2, 6.1.1.3, 6.1.4.1	+	+	+	+	+
	b) use molapo fields for rainfed cropping	5.1.2.2	-	-	+	+	+
5. Reduction of area planted	a) concentrate efforts on smaller area *)	5.1.2.2, 6.1.1.3	+	+ +	+	+	+
	b) shift over field, introducing fallow	5.1.2.2	+	+	+	+	+
IMPROVED CROP MANAGEMENT							
6. Improved crop husbandry	a) timely migration to the lands and timely preparations	5.1.2.3	+	+	+	+	+
	b) improved draught power situation *)	5.1.2.3	+ +	+	+	+	+
	c) timely planting from NOV3 after 20mm of rain *)	5.1.2.3, 6.1.1.3	±	+	+ +	+ +	+ +
	d) reduction of planting opportunities *)	6.1.1.3	+ +	+ +	+ +	+ +	+ +
	e) conduct a harrowing operation	5.1.2.3	-	-	±	+	+
	f) carry out row planting and crop rotation *)	5.1.2.3	±	±	+	+	+
	g) use 15,000 plants/ha (do thinning and gap filling) *)	5.1.2.3	+	+	+	+	+
	h) plant groundnut and sorghum (most profitable crops on 6 land units of 4a) under all management scenarios *)	6.1.1.3	+	+	+	+	+
	i) plant maize always before DEC3 *)	6.1.1.3	-	-	±	±	+
	j) plant groundnut late in one go (lm2) or early in 1 or 2 plant occasions (Op1 or lm3) on all land units *)	6.1.1.3, 6.1.4.1	±	+	+	+	+
	k) plant sorghum late in one go (lm2) or early in 2 plant occasions (lm3) on SV2, LS2, AS3 *)	6.1.1.3, 6.1.4.1	±	+	+	+	+
	l) plant sorghum early in 2 plant occasions (lm3) on AS2, LS1, SV1 *)	6.1.1.3, 6.1.4.1	±	+	+	+	+

	m) do not use fertilizer, when practicing lm1 *)	6.1.1.3, 6.1.4.1	+	+	+	+	+
	n) do not use fertilizer for maize, when practicing lm2 *)	6.1.1.3, 6.1.4.1	+	+	+	+	+
	o) use upto 10 ppm P fertilizer on SV2, LS2, AS3 for sorghum, millet, groundnut under lm2 management *)	6.1.1.3, 6.1.4.1	-	-	+	+	+ +
	p) use upto 6 ppm P fertilizer on all land units for sorghum, millet, groundnut under lm2 management *)	6.1.1.3, 6.1.4.1	±	±	+	+	+
	q) do not use fertilizer for cowpea on SV2, LS2, AS3 under lm2 management *)	6.1.1.3, 6.1.4.1	+	+	+	+	+
	r) use upto 6 ppm P fertilizer on AS2, LS1, SV1 for cowpea under lm2 management *)	6.1.1.3, 6.1.4.1	±	±	+	+	+
	s) use upto 10 ppm P fertilizer on SV2, LS2, AS3 for maize, sorghum, millet, groundnut under lm3 *)	6.1.1.3, 6.1.4.1	-	-	+	+	+ +
	t) use upto 6 ppm P fertilizer on AS2, LS1, SV1 for maize, sorghum, millet, groundnut under lm3 *)	6.1.1.3, 6.1.4.1	±	±	+	+	+
	u) do not use any fertilizer for cowpea on SV2, LS2, AS3 under lm3 management *)	6.1.1.3, 6.1.4.1	+	+	+	+	+
	v) use upto 10 ppm P fertilizer for cowpea on AS2, LS1, SV1 under lm3 management *)	6.1.1.3, 6.1.4.1	-	-	+	+	+ +
	w) use upto 6 ppm P fertilizer for all crops on all land units under Op1 management *)	6.1.1.3, 6.1.4.1	-	-	+	+	+ +
	x) conduct adequate pest management	6.1.3	±	±	+	+	+ +
	y) conduct timely weeding *)	5.1.2.3	+	+	+	+	+
	z) conduct adequate bird scaring	5.1.2.3	+	+	+	+	+
7. Application of alternative management practices	a) spreading of land preparations on sandy soils *)	5.1.2.3	-	-	±	+	+
	b) dry ploughing/planting on sandy soils *)	5.1.2.3	-	-	±	+	+
8. Diversification/use of alternative crops	a) use of drought resistant, early maturing varieties	5.1.2.3	+	+	+	+	+ +
	b) use of alternative crops	6.1.2, 6.1.4.2	±	±	+	+	+ +

ad 4a) - Generally, without fertilizer all crops perform best on the land units SV2, LS2 and AS3, which have soils containing slightly more clay (all within 20% significance). The land units AS2, LS1 and SV1 (sandy soils throughout) are slightly less productive without fertilizer. With fertilizer the latter soils perform similar as the soils of the depressions.

ad 5a) - The major advantages of utilizing smaller fields are:
  * planting will be finished earlier, hence more time will be available to look after the crops (weeding, bird scaring and pest/disease control)
  * re-introduction of a fallow period in the crop rotation
  * reduction of the pressure on land
  * 0.5 ha is a tract of land, that can be ploughed/planted with draught animals in 3-4 days.

ad 6b) - Households without draught power should get access to a package through ALDEP.

ad 6c) - Timely planting is a major recommendation, but is difficult to fulfill by poor households (P1 and P2) with often a labour, draught power and implement shortage.
- When planting can take place earlier, e.g. between November 21 and December 20, yields will be higher in all cases, making the arable activities more profitable. A positive side effect of planting earlier will also be the reduction of the hectarage required to produce the same yield as on a larger field using more planting opportunities.
- The following can be used as a guideline for yield prediction:
  * early planting in 1 plant opportunity: highest yield
  * early planting in 3 plant opportunities: intermediate yields
  * late planting in 3 plant opportunities: lowest yields.

ad 6d) - Timely planting (from NOV3 onwards) instead of late planting (from DEC3 onwards) goes above the reduction of the number of planting opportunities (when used more than 1), as far as yield improvement is concerned. Early planting using 3 or 4 planting opportunities pays off compared to late planting in 2 occasions.
- When 1 planting opportunities is used, late planting is more productive than early planting using 3 or more planting opportunities. Early planting using 2 planting opportunities, however, is more effective, than late planting utilizing 1 plant occasion.
- Early planting with 1 or 2 plant opportunities is more profitable than early planting in 3 occasions.

ad 6f) - Row planting is also possible by hand hoe on small hectarage, for those farmers who have no access to a row planter.
- Rotation of grain crops and legumes is to be recommended. Cowpea is a common crop in the extension area, but is usually grown in small hectarages. Farmers say cowpea does well, even under low rainfall conditions. Groundnut has also been observed to do well, but is not common. The legumes cowpea and groundnut are beneficial for the improvement of the soil fertility. They also have greater value than cereals and do not require bird scaring. Farmers should be encouraged to grow them at larger portions of their fields. Seeds should be made available in larger quantities, both at para-statals and in private enterprises.

ad 6g) - It is recommended to strive for 15,000 plants/ha for all crops. Where necessary a thinning and/or gap filling operation should be conducted, assuring an optimal use of the available soil moisture, the formation of a couple of tillers (sorghum) and proper development of heads and grain filling.

ad 6h) - From the simulated baseline management systems, Bs4 (early planting from NOV3-FEB1 after 20mm of rain, using 3 planting opportunities) results in the highest yields and financial returns for all CYSLAMB crops (maize, sorghum, millet, cowpea and groundnut). Groundnut, followed by sorghum is the most profitable crop. Millet and cowpea perform moderately well, while maize delivers the lowest financial returns.
- From the intermediate scenarios simulated by CYSLAMB, groundnut proves the most profitable (sorghum achieves the highest yield), followed by sorghum, millet, cowpea and last maize.
- Using the optimal scenario, sorghum is the highest yielding crop. Groundnut is the most profitable crop, followed by sorghum, maize and millet. Cowpea achieves lowest gross margins.

ad 6i) - Maize is the most draught sensitive crop from the 5 CYSLAMB crops and shows the lowest financial returns, when grown under a baseline or an intermediate management system. Under optimal conditions it performs similar to millet and somewhat better than cowpea.

ad 6j) - This recommendations leads to the same gross margins, when comparing situations without and with the use of fertilizer, both 6 and 10 ppm P, respectively. Even the results of management system Op1 (early planting, 1 opportunity) do not significantly differ.

ad 6k) - This recommendations leads to the same gross margins on the land units SV2, LS2, AS3, when comparing situations without and with the use of fertilizer, both 6 and 10 ppm P, respectively.

ad 6l) - On the land units AS2, LS1, SV1 all Im3 scenarios for sorghum lead to significantly higher gross margins than the Im1 and Im2 scenarios.

ad 6m) - For any crop on any land unit, the management systems Im1_6 and Im1_10 (late planting, using 2 planting opportunities and fertilizer) are not profitable.
- Early planting without fertilizer using 3 or 4 planting opportunities (Bs2 or Bs4) pays off, compared to late planting with fertilizer upto 6 or 10 ppm P in 2 occasions (Im1_6 or Im1_10).

ad 6n) - For maize on any land unit, the management systems Im2_6 and Im2_10 (late planting, using 1 planting opportunity and fertilizer) are not profitable, compared to the scenarios Bs2 and Bs4.

ad 6o) - Im2_10 is more profitable than Im2_6 for sorghum, millet and groundnut on land units SV2, LS2, AS3.

ad 6p) - Im2_6 is more profitable than Im2_10 for sorghum, millet and groundnut on land units AS2, LS1, SV1.

ad 6q) - Im2_0 is more profitable than Im2_6 and Im2_10 for cowpea on land units SV2, LS2, AS3.

ad 6r) - Im2_6 is more profitable than Im2_10 for cowpea on land units AS2, LS1, SV1.

ad 6s) - Im3_10 is significantly more profitable than Im3_0 (early planting, using 2 planting opportunities and no fertilizer) as compared to Im3_6 for maize, sorghum, millet, groundnut on land units SV2, LS2, AS3.

ad 6t) - Im3_10 is not significantly more profitable than Im3_6 for maize, sorghum, millet, groundnut on land units AS2, LS1, SV1; so scenario Im3_6 is recommendable.

ad 6u) - Im3_6 and Im3_10 are not more profitable than Im3_0 for cowpea on land units SV2, LS2, AS3.

ad 6v) - Im3_10 is significantly more profitable than Im3_0 (early planting, using 2 planting opportunities and no fertilizer) as compared to Im3_6 for cowpea on land units AS2, LS1, SV1.

ad 6w) - Op1_6 (early planting, using 1 plant opportunity and fertilizer upto 6 ppm P) is significantly more profitable than Op1_10 for all crops on all land units.

ad 6y) - Weeding is usually done when weeds are ankle to knee high, which corresponds with 30 days after planting. This practice should be continued.

ad 7a) - In the North Western Region, certainly around Maun, CYSLAMB identifies the first planting opportunity in NOV3 or DEC1 in approximately 80% of the years. Given this statistical fact, spreading of operations should be considered, when land preparations form a constraint.

ad 7b) - Planting done from NOV2 onwards (just before the first planting rains), will provide the seeds optimal advantage of the rain of the first planting opportunity of the season. Planting too early (before NOV2) might lead to crop failure due to a lack of soil moisture.

With the above recommendations at hand, the AD and CPO should be well equipped to provide extension messages, adapted to the prevailing agro-ecological circumstances and targeted to the possibilities of the target farmer groups. When approaching a farming household, the extension worker should check to which group the client belongs, and then provide an array of recommendations accordingly. However, a certain flexibility should be taken into consideration. If a farmer is prepared to try out a recommendation originally targeted to an other group, he/she should be well informed, but fully supported.

In case a farmer from a specific group wants to know what his/her options are to grow a specific crop on a particular land unit, his/her management capabilities (labour, time and financial limitations) should be assessed. An appropriate management scenario can be advised according the Tables 25-30 and 32-34. The last three tables directly show the financial implications of the different management options.

A recapitulation of the above per farmer group is given in Table 57 and in the subsequent paragraphs of this section.

Table 57. Summary of important recommendations for rainfed arable farming per farmer group

P1	P2	W1	W2	R1
			---- Agroforestry (wind breaks/mulching) ----	
	--------- Cultivation of smaller areas ---------			
improved draught power				
	------------------ Timely planting ------------------			
------------------------- Reduction of planting opportunities -------------------------				
		--------- Row planting and crop rotation ---------		
----- Fertilizer upto 0-6 ppm P -----		----- Fertilizer upto 6-10 ppm P -----		Fertilizer 10 ppm P
----- Plant sorghum and groundnut -----		----- Plant sorghum, groundnut, millet -----		Try maize, cowpea
			----- Alternative management practices -----	
		--------- Introduction of alternative crops ---------		

Farmer group P1

This farmer group mainly consists of female headed households with modest resources and available labour. In order to improve their rainfed crop production, members of this group should try to acquire one or two donkeys and a plough through ALDEP, in order to be able to conduct their operations independently and timely. Although already cultivating areas with a maximum of 2 ha, efforts should be concentrated on small portions of the field in a maximum of two planting opportunities. When not enough draught power and/or implements are available, a hand hoe can be used for (row) planting, as most of the soils have a sandy topsoil. Fertilizer is probably not affordable for this group, but when some cash is available the phosphorus content of the topsoil should preferably be raised to 6 ppm P. Sorghum and groundnut are the most recommendable crops, as they give the highest yields and financial returns per hectare. Timely weeding, adequate bird scaring and prompt harvesting of sorghum should be strived for. Bird damage can be considerably reduced, by having sorghum ripening off, accumulated on racks near the homestead.

Farmer group P2

This is the largest group of farmers in the study area. Although having limited resources, most of these households possess a minimum of four donkeys. When two spans are used alternatingly, the number of planting opportunities can be reduced to two. This should be combined with a reduction of the area cultivated to approximately 2 ha. Planting should start from NOV3 onwards. These farmers should purchase a plough through ALDEP. Fertilizer is probably not affordable for this group, but when some cash is available the phosphorus content of the topsoil can be raised upto 6 ppm P. Sorghum and groundnut are the most recommendable crops, as they give the highest yields and financial returns per hectare. Timely weeding, adequate bird scaring and prompt harvesting of sorghum should be strived for. Crop residue should be ploughed back in the soil after the harvest in order to maintain the soil fertility levels.

Farmer group W1

Farmers belonging to this group are well-off and normally possess draught power and a plough. Members of this group should be able to overcome possible labour shortages by hiring casual labour. This group is recommended to limit the area planted to 2-5 ha and to use a maximum of 2-3 planting opportunities. Planting should start from NOV3 onwards. Farmers are recommended to buy a rowplanter. It is advised, that 2/3 of the area cultivated is row planted. The remaining 1/3 could be broadcasted. The use of kraal manure and where appropriate inorganic fertilizer can be recommended. The phosphorus content of the topsoil should be raised upto 6-10 ppm P, while in addition a rotation of grain crops and legumes should be practiced. Besides the most profitable crops sorghum and groundnut, millet could be grown when preferred. Adequate pest management should be practiced. In order to diversify, the introduction of alternative crops on a small portion of the field is strongly recommended. When access to a field is assured, production can be considerably increased by using a molapo field.

Farmer group W2

This group of well-off farmers does not have many limitations regarding crop production. They are, however, recommended to limited the area planted to 2-5 ha and to utilize a maximum of 2-3 planting opportunities. Planting should start from NOV3 onwards. Conducting a harrowing operation should be encouraged. It is advised, that 2/3 of the area cultivated is row planted. The remaining 1/3 could be broadcasted. The use of kraal manure, and where appropriate inorganic fertilizer can be recommended. The phosphorus content of the topsoil should be raised upto 6-10 ppm P. A rotation of grain crops and legumes should be practiced. Besides the most profitable crops sorghum and groundnut, millet could be grown when preferred. Adequate pest management should be practiced. In order to diversify, the introduction of alternative crops on a small portion of the field is strongly recommended. When access to a field is assured, production can be increased considerably by using a molapo field. The introduction of alternative management practices as spreading of the land preparations on sandy soils and dry ploughing/planting could be considered on a small portion of the field. Agroforestry techniques are recommended for a multitude of purposes: wind erosion control, improvement of topsoil organic matter content (mulching), fuelwood supply and fodder for livestock.

Farmer group R1

This group consists entirely of male headed households without resource limitations. They are recommended to cultivate an area of 5 ha and to use maximally 2 planting opportunities. Planting should start from NOV3 onwards. Conducting a harrowing operation should be encouraged. It is advised, that 2/3 of the area cultivated is row planted. Inorganic fertilizer should be used, raising the phosphorus content of the topsoil upto 10 ppm P, where appropriate. Grain-legume crop rotation should be practiced. Besides the most profitable crops sorghum, groundnut and millet, this group can afford to try growing the more drought sensitive maize and the less profitable cowpea. Adequate pest management should be practiced. In order to diversify, the introduction of alternative crops on a reasonable scale is strongly recommended. The introduction of alternative management practices as spreading of the land preparations on sandy soils and dry ploughing/planting are advised on a portion of the field. Agroforestry techniques are highly recommended for a variety of reasons: wind erosion control, improvement of topsoil organic matter content (mulching), fuelwood supply and fodder for livestock.

Apart from the above evaluated 'standard' crops (maize, sorghum, millet, cowpea and groundnut) an overview is given from the most suitable 'alternative' crops. Two types have been distinguished: cash crops (cluster bean, devil's claw, hibiscus, jugo bean, pigeon pea, prickly pear, sesame, sisal and sunflower) and fodder crops (buffel grass, lablab bean, moth bean and siratro). See Sections 6.1.2 and 6.1.4.2.

7.1.1.2 Grain subsistence ratio

The following calculation of the grain subsistence ratio (the relationship between the calorie availability and requirements) is made for the total population of the Chanoga AEA after the example prepared by Wijesuriya and Phillime (1994). The assessment is based on the assumption, that the entire area cultivated (872 ha) in 1993/94 was used for the growing of sorghum.

When sorghum was grown under the baseline management scenario Bs3 (late planting, using 3 planting opportunities and no fertilizer), the total amount of calories produced does not meet the calories required by the 1201 people living in the area in 1994, see Table 58.

Table 58. Calculation of grain subsistence ratio based on sorghum yields

PARAMETER	QUANTITY	UNIT
Total population anno 1994	1201	persons
Total number of households	218	households
Total adult equivalents *)	993.5	adult equivalent
Annual calorie requirements **)	943.8×10^6	Cals
Sorghum yield (CYSLAMB management system Bs3)	140 ***)	kg/ha
Calorie content of sorghum	3400	Cals/kg
Total calorie yield	0.48×10^6	Cals/ha
Total calorie production from cultivated area (872 ha)	415×10^6	Cals
Subsistence ratio (availability/requirement)	0.44	
Sorghum yield (CYSLAMB management system Im3)	440 ***)	kg/ha
Total calorie yield	1.50×10^6	Cals/ha
Total calorie production from cultivated area (872 ha)	1304×10^6	Cals
Subsistence ratio (availability/requirement)	1.38	
Total population anno 2004	1513	persons
Total adult equivalents *)	1252	adult equivalent
Annual calorie requirements **)	1189×10^6	Cals
Subsistence ratio (scenario Im3 and cultivated area 872 ha)	1.1	

*) based on 5.5 persons per household, corresponding to 4.55 adult equivalent
**) based on a requirement of 0.95×10^6 Cals/yr/adult equivalent
***) dependable yield (averaged over land units AS2, AS3, LS1, LS2, SV1 and SV2)

In order to meet the calories required (a subsistence ratio of 1), with an unchanged management scenario, the area cultivated has to be enlarged with 502 ha. That will bring the total area cultivated at 1374, being 89% of baseline area of the Chanoga AEA. This is a rather unrealistic option, which would mean an average area to cultivate of 6.3 ha/household. It is more recommendable to maintain or reduce the area planted in combination with the adoptation of the improved management scenario Im3 (early planting, using 2 plant occasions) or the optimal scenario Op1 (early planting, using 1 plant occasion).

Given the 1994 population figure and the introduction of management system Im3, the subsistence ratio would easily be met. The ratio of 1.38 indicates the production of a grain surplus. With the Im3 management scenario, an increased population to 1513 people for the year 2004 and the same area cultivated, the subsistence ratio would still be 1.1, indicating a small surplus. In other words, when the area cultivated remains the same (872 ha), just enough land is planted to meet the subsistence requirements (ratio 1.1) of the expanding population (1513 in year 2004).

7.1.2 Improved molapo farming

Although proper flooding by the Boteti River is limited, molapo farming should be encouraged in years of suitable hydrological circumstances. It provides farmers the opportunity to successfully grow maize, the grain crop that is marginally suitable under the prevailing rainfed conditions. Even under traditional management, molapo maize yields equal or exceed the yields achieved under the optimum rainfed scenario. By introducing several improvements in the baseline molapo management system, like a harrowing operation, row planting, crop rotation, an increased plant density and the use of fertilizer, molapo farming has a great potential for yield improvements. See Section 6.2.

7.1.3 Small scale horticulture, beekeeping and agroforestry projects

7.1.3.1 Home vegetable garden and backyard nursery/orchard

Home vegetable garden

In the framework of diversification a home vegetable garden can be considered by farmers with limited resources. Initially the produce will be for home consumption and will thus contribute to an increase in the nutrition level of individual household members. When a small surplus is produced, sales will contribute to the household cash income.

Three conditions will have to be fulfilled before a successful garden can be started. Access to water should be assured, knowledge of vegetable growing should be acquired and some cash is needed to cover the initial expenses. See Section 6.3.1.1.

Backyard nursery and orchard

The sales of tree seedlings, raised in a backyard nursery and fruits from trees of a small orchard on the compound can form an alternative source of income for rural families.

With a modest starting capital and access to water these two tree based production systems are well realizable. They can contribute to the diversification of the rural households agricultural activities. See Section 6.3.1.2.

7.1.3.2 Small scale beekeeping projects

The production of comb honey and wax is an income generating activity, that is not practiced in the study area. With modest starting capital and labour input, a lucrative enterprise could be set up, initially based on a few hives and with room for future expansion. See Section 6.3.2.

7.1.3.3 Agroforestry systems

Looking for measures to combat the occurring wind erosion on arable fields, two agroforestry based systems are proposed for the study area. Apart from erosion control measures, the two systems can serve as a source of mulch to improve the topsoil fertility levels, as a source of fodder, fuelwood and building materials, fruits and medicine.

The first system consists of the planting of hedge rows and tree wind breaks perpendicular to the dominating wind direction across the farmers' fields. The second system involves tree wind breaks across the fields and a life perimeter fence around them. System designs and suitable shrub and tree species are given. See Section 6.3.3.

When the prerequisites (water, adequate protection of seedlings against livestock and smallstock and dedicated maintenance) are fulfilled, these agroforestry based systems can have a multiple positive result. It is recommended that several pilot projects are set up with selected farmers, in cooperation with the Forestry Section and the Soil Conservation Office of the RAO Maun.

7.1.4 Improved livestock production systems

Most conclusions and recommendations presented in this section are related to cattle production systems and are based on APSRAMB simulations. Only two small alternative animal based production systems have been evaluated.

7.1.4.1 Recommendations regarding animal husbandry

Available biomass

As was shown in Section 6.4.2.1, the biomass produced in both grazing areas A (around the villages) and B (around the cattleposts) is on average sufficient to sustain the actual (situation before CBPP outbreak) amount of animals grazing (both cattle and other livestock and smallstock). In fact, in average rainfall years a surplus of grass exists. However, as the digestibility of most grass species is relatively low, and dry matter intake by animals limited, a contradictory situation occurs, where animals have problems feeding enough to gain weight.

Seen in this light, no adequate method to evaluate the present stocking rates has been developed yet. The general feeling is, that the southern portion of grazing area A (along the Boteti River) is somewhat under pressure, due to daily movement of cattle for watering. Caution for overgrazing of the alluvial land units should be practiced. The grazing area B (northern portion of the sandveld) seems to produce abundant biomass for the existing stock numbers. A slight increase in numbers, along with some controlled grazing measures (see Section 7.1.4.3) could be considered.

Herd development

APSRAMB simulations of the village and cattlepost production systems learned the following:

1. Controlled breeding (calves born in times of ample availability of fresh biomass) proved very successful; the tested cattlepost herd expanded rapidly. This recommendation is easier to carry out in a cattlepost situation than in a village grazing system, where cows meet bulls by chance. However, through herding under strict supervision, and keeping steers separate from cows, even breeding under the village situation could be regulated to an extend.
2. Supplementary feed given in years with below average rainfall and range biomass production is a promising option. In the improved village grazing system ECv_i, it prevented the plunge in size of the small herd, as occurred in the traditional village production system ECv. A proper costing of this intervention should be made, though, and included in a financial analysis of both improved systems (village and cattlepost). It probably turns out an expensive option, which is only viable for medium to large scale enterprises (cattlepost system ECc_i).
3. Increased offtake rates, simulated by an increase in sales, seemed to result in a slower growth of the small herd under the improved village grazing system ECv_i than under the traditional system ECv. However, a steady cash inflow is achieved over a long period of time. In case of drought, at least a considerable sum can be recuperated, before a large number of animals out of the herd dies. It seems, that a certain number of fit and strong animals survive a drought, irrespective of the number of animals sold. In the situation of the growing herd under the improved cattlepost production system ECc_i, sales grew proportionately, whereas they stayed constant under the traditional cattlepost situation ECc. It should be investigated, how the sales can be increased, in order to achieve a stable optimal herd composition and to guarantee a sustainable use of the range resource.

Animal health and (re)production

Farmers are strongly recommended to increase the condition of their cattle by using more inputs like dicalcium phosphate, drought pellets, cattle blocks and salt licks. An improved cattle condition, will result in a higher grading and a rise in income from sales. Mentioned inputs can be given for a limited period of time to those animals selected for sales.

Many of the interviewed farmers from the study area suggested the construction of a communal cattle dip tank, as a measure to increase the animal health situation. Arrangements should also be made to reopen the Makalamabedi AI Camp, in order to restart providing AI service.

7.1.4.2 Recommendations regarding the water situation

In order to alleviate the grazing pressure along the Boteti River, to overcome the shortage of water in well points and to reduce the daily walking distance of animals (hence to improve their overall condition), the government should investigate the means to assist the small cattle owners in the settlements (production systems ECv and ECv_i). Boreholes drilled on the north bank of the Boteti River are yielding large amounts of fresh water. This should be reticulated to the southern portion of the sandveld, which belongs to the village grazing area A. Two problems should be overcome. Livestock owners should be motivated to join in water development syndicates and Land Board should provide a certificate for the drilled boreholes on the river bank, in order for the communities to be eligible for government assistance.

7.1.4.3 Recommendations regarding controlled grazing

The above suggested solution for the watering problems of livestock kept around the settlements should be considered in combination with the sustainable use of the availability of grazing resource. It should be investigated, to what extent the communities are interested in setting aside a portion of the grazing area during a part of the year, which then can be used in times of scarceness of grasses. This will confine cattle in a smaller area and make them walk smaller distances and graze more efficiently. One way to control grazing is the introduction of a communal paddocking system. An other way, at a slightly smaller scale, would be the formation of syndicate ranches, with internal grazing compartments.

Granted that water can be provided, the southern portion of the sandveld could be considered for controlled grazing experiments. Groups of farmers that decide to start controlled grazing projects, can make use of the fencing component of the New Agricultural Policy. The government should be able to assist them with fencing and water development under this scheme.

7.1.4.4 Cattle rearing after the eradication of the CBPP

Before the restocking takes place in the Ngamiland District, a land use planning exercise should be conducted with the following objectives and activities:

- a range assessment, in order to estimate sustainable stocking rates
- a socio-economic study to investigate the readiness of farmers for the creation of cattle syndicates, in order to carry out the fencing component of the New Agricultural Policy
- the introduction of paddocking in large communal grazing area blocks through the use of (drift) fences.

Through such a study sustainable cattle production systems can be designed, adapted to the needs and wishes of specific farmer groups. Also areas with resource shortages (grazing or water) can be identified and mapped and appropriate control measures can be put in place.

7.1.4.5 Alternative small scale duck and chicken production

Two alternative animal based production systems, that can be practiced separately or in conjunction, have been evaluated. The rearing of ducks and the production of chicken eggs with layers can be carried out on a very modest scale for a start and when successful, production can be increased.

The future entrepreneur should have access to a reliable water source and a modest starting capital. See Section 6.4.6.

7.1.5 Improved use of veld products

As the use of veld products is of a crucial importance to many households in the study area, but most of all to members of the most resource poor farmer groups P1 and P2, efforts to improve the utilization of the vegetative resources should concentrate on the following points:

1. An increase of the awareness amongst the population with regard to the value of the standing biomass and the development of sustainable harvesting techniques and 'quota'.
2. The feasibility of the creation of a veld product marketing board or association with the help of a NGO. Possibly a pilot project could be started in the Chanoga AEA and when successful expansion to other areas of the Ngamiland District or elsewhere in the country can be considered.
3. The feasibility of the establishment of a *Colophospermum mopane* coppicing project in the northwestern corner of the AEA through the Mawana VDC. See Section 6.5.

7.1.6 Improved wildlife utilization

If the Department of Wildlife and National Parks would like to increase its income from the controlled hunting area NG35, in which the Chanoga AEA is situated, it is recommended to either raise the single game license fees for citizens or to change the use of NG35 (introduction of other types of wildlife utilization, like tourist trophy hunting or wildlife/cattle ranching) and the quota accordingly. See Section 6.6.

7.2 Improved farmers' well being

This section deals with recommendations, not only meant to improve the present production systems, but most of all to improve the farmers' well being in general and to facilitate production and handling of produce.

7.2.1 Solutions to water shortage

From the farm survey it appeared, that the chronic water shortage both for domestic consumption and for livestock watering is experienced by the farmers as their largest constraint.

Despite the daily filled Council water tanks, that were installed mid 1996, it is recommended that the settlements of Mawana, Tsibogolamatebele and Xhana are provided with water in a more structural way. Water could be reticulated from Maun or Chanoga or from boreholes to be drilled along the Boteti River.

Through the ALDEP subsidy scheme more efforts should be undertaken to promote the use of water catchment tanks to be installed in the lands areas, in order to alleviate water shortages of farming families and draught animals during the cropping season. See Section 5.6.2.1.

Watering problems for livestock (mainly cattle) can be considered in combination with the availability of grazing. When communities would decide to make use of the fencing component of the New Agricultural Policy, syndicate ranches could be formed in the sandveld area. In the framework of government's assistance to small cattle owners, boreholes can be developed in the ranches. This will make cattle independent from well points in the Boteti River bed and will relieve the grazing pressure on its banks. See Sections 7.1.4.2 and 7.1.4.3.

7.2.2 Improved institutional support

A better equipped extension service, more precisely targeted government support packages and improved marketing channels will increase farmers' motivation to invest time and money in the improvement of existing or the development of new agriculture related enterprises. The following sections contain recommendations, that not only apply to the Chanoga AEA, but to the Ngamiland District as a whole.

7.2.2.1 Improved extension service

A number of recommendations are made aiming at improving the agricultural extension service. The suggestions concern both Ads and VAs.

1. Provide ADs/VAs with base maps (topography, soils, vegetation) of their extension area. Organize a training course aimed at using these maps and to produce land use maps of their areas.
2. Improve the transport situation for extension workers. Especially in large, remote extension areas farmers are hard to reach and the mobility of ADs/VAs should be increased. It should be investigated, whether government can supply transport facilities (on a rotational basis), or else, whether loans or subsidies can be given to ADs/VAs to purchase their own adequate means of transport (horse, bike, motorbike or car).
3. ADs/VAs should be equipped with comprehensive extension packages, compatible with the prevailing agro-ecological conditions and targeted to farmer groups with specific resource availabilities, both as far as crop and livestock production is concerned. The recommendations formulated in this report may serve as an example.
4. More creative and illustrative ways of transferring extension messages should be developed. In this way the extension staff might become more confident and motivated to assist farmers, resulting in an increased convincing power and a higher adoptation rate of extension messages and use of assistance programmes.
5. Reintroduce the farmers' record cards for better targeting of extension messages.
6. Appointment of drought relief administrators during arable Drought Relief programmes, in order to let ADs concentrate on extension work.
7. Harmonization of AD and VA extension area boundaries, in order to combine efforts as an integrated agricultural extension team and to share resources.

See Sections 5.1.2.4 and 5.4.2.3.

7.2.2.2 Adoptation of government support packages and subsidies

Present and future government support packages and subsidy schemes should be fine tuned, made easier obtainable for farmers (less pre-conditions, easier to apply for and quicker delivery), and be more production oriented, in order to achieve higher adoption rates. Some suggestions for the improvement of the ALDEP programme and the arable Drought Relief scheme are made below:

The ALDEP programme should step up its efforts to provide basic packages, like draught power and implements to the most resource poor farmer groups. In this way farming households can become independent and are better prepared to following crop production increasing recommendations. ALDEP packages should be more production oriented and contain e.g. drought tolerant, early maturing grain varieties, legume seeds and fertilizer. In order to increase farmers' mobility, the scotch cart should be made available to farmers, who possess draught power. By being more mobile, market centres can more easily be visited to purchase inputs and sell surplus produce. A means of transport will also alleviate carting water for domestic consumption and increases the possibilities to apply kraal manure on the fields. Regarding technology transfer in ALDEP Phase II, appropriate recommendation packages should be compiled for target farmer groups, suited to the prevailing agro-ecological conditions. See Sections 5.1.1.3 and 5.1.2.4.

Future arable drought relief subsidies should be provided in packages geared towards improving the existing crop production systems and towards diversification. Ploughing subsidies should be limited to 3 hectares per farmer, and only granted when timely ploughing was carried out. Legume and/or sunflower seeds should be distributed to a maximum of 2 hectares per farmer, as well as seed and fruit tree seedlings for a home vegetable garden and a small orchard. See Sections 5.1.1.3 and 5.1.2.4.

The creation of a farmers' credit/saving scheme should be given more thought. Especially the groups of poor farming households should be given the opportunity to break the downward spiral of their financial situation. Through a system of soft loans they can be given the chance to invest in inputs or labour, to improve their production systems. The government should stand guarantee for those, who have no collateral against their loan. When repayments are made in time, people should be eligible for a higher loan. When once failed to repay, a new loan should be given one more time; after a second failure to repay, no further government subsidies should be granted until the obligations have been fulfilled. Saving facilities should be created for farmers, who generate a cash income through the sales of a crop surplus, livestock or veld products. Possibly a mobile service can be established. Extension concerning banking facilities should be given priority.

7.2.2.3 Improved marketing facilities

Farmers should be given more incentives to increase their rainfed crop production. This could be achieved through modified BAMB and BCU services and by a higher degree of involvement of the private sector.

In order to improve the availability of inputs (implements, seed and fertilizer), inputs should be brought closer to farmers. BAMB should start a mobile service. To encourage farmers to sell grain surpluses, a network of lock-up stores should be build at a central point in each extension area, backed up by a BAMB Depot in each agricultural district. After the harvest, a mobile BAMB facility should purchase farmers' surpluses from the lock-up stores.

Private enterprises should be persuaded to play a more active role in the timely supply of inputs, like (legume) seeds, fertilizer and pesticides, in order for motivated farmers to react swiftly upon the changing climatic and crop conditions. See Sections 5.1.1.3 and 5.1.2.4.

Regarding animal production the LAC, like BAMB, should restructure its services in supplying livestock owners with the appropriate implements, medicine and feeds.

A proper smallstock processing plant is needed to raise the existing extensive smallstock production systems with very low off-take rates to a semi-commercial level. To facilitate the marketing of cattle from small owners, it could be considered to form local marketing groups, coordinated by an NGO. At set times during the year cattle could collectively be sold. BLDC could play a more prominent role in cattle marketing at village level. Government should stimulate offtake by bonus schemes. See Section 5.4.2.3.

7.2.3 Suggestions for small scale village based (agro-)industries

In a bid to break the trend of decreasing rural incomes during times of drought, farmers should be encouraged to engage themselves in alternative income generating activities. Some of the proposed activities are agriculture related, most are small scale industries, that can easily be established in rural settlements. Where applicable training courses should be organized and assistance with the purchase of supplies and marketing of the final products should be assured, possibly by an NGO. The following list of suggestions does not have the pretention to be exhaustive:

- blacksmithing (repair of implements, make donkey carts, tubs/buckets etc.)
- carpentry
- craft centre + training courses (production of baskets, ostrich egg shell necklaces and bracelets, decorated eggs, paintings, wood carvings, clay statues and pottery)
- creameries (sour milk, cream and cheese production)
- grain mill
- oil production plant from groundnuts or sunflower seeds
- rope making from sisal or *Sansevieria*
- tanneries (processing of hides and skins)

See Section 5.6.2.2.

7.2.4 Infrastructural improvements

In order to modify the rural character of the AEA and to provide access to the rapidly developing modern society, several infrastructural improvements should be realized.

Feeder roads between the settlements and the main tarred Nata-Maun should be upgraded.

Connections should be made to the national electricity and telephone grids (certainly useful for extension services, schools, clinic and other institutions). Especially as the new power line runs across the AEA and microwave telephone towers have been placed in the area, both linking Maun to the nationwide facilities. Since August 1996, telephones have been installed in the village of Chanoga.

The installation of alternative sources of power like solar panels and small windmills to provide electricity to small industries, could also be considered.

7.3 Recommended land use

As the focus of this study was not on the rezoning of the land, but more on the development of recommendations to improve the existing production systems, no major changes in land use types are proposed. Table 59 below indicates on a land unit basis the dominant present land use, the suitability of the land units for specific uses and the recommended land use. The reflected suitabilities are oversimplified. The last column of Table 59 gives references to the relevant sections in this report, that deal with the evaluation of the present and the recommended land uses.

A Land Suitability Map (scale 1:120,000) for a combination of rainfed arable farming and rangeland production has been compiled, based on the results of the suitability evaluations conducted in Chapter 6. Four crop suitability classes were distinguished with CYSLAMB, based on the growth of sorghum under the optimal management system without fertilizer use, Op1_0. Four rangeland production classes were recognized with APSRAMB, based on the biomass production of herbaceous strata. For each land unit the combination of the suitabilities for rainfed arable farming and rangeland production was assessed. Although very crude, the Land Suitability Map, see Annex C, visualizes the potential of each land unit for the two major land uses.

Table 59. Suitability and recommended land use per land unit

LAND UNIT	AREA	DOMINANT PRESENT LAND USE	SUITABILITY RF	MF	HG	BN	BK	AF	CC	DC	VP	WU	RECOMMENDED LAND USE	SECTION of REPORT
AS1	1590	veld products, extensive grazing, molapo farming	–	+	–	–	+	–	±	–	+	–	improved VP, BK, MF	6.2, 6.3, 6.5
AS2	8266	rainfed farming, extensive grazing, settlements	±	–	+	+	+	±	±	+	+	–	HG, BN, BK, DC	6.3, 6.4
AS3	2829	extensive grazing	+	–	+	+	+	–	+	+	–	–	improved RF, HG, BN, BK, DC	6.1, 6.3, 6.4
AS4	569	extensive grazing	–	–	–	–	–	–	±	–	–	–	no change	–
LS1	3457	extensive grazing, veld products	±	–	–	–	–	–	+	–	+	+	improved grazing/WU and VP	6.4, 6.5, 6.6
LS2	916	extensive grazing	+	–	–	–	–	–	±	–	–	+	improved RF	6.1
LS3	168	extensive grazing	–	–	–	–	–	–	±	–	–	+	no change	–
SV1	36694	rainfed farming, extensive grazing, veld products	±	–	±	±	±	±	+	±	+	+	improved grazing/WU and VP	6.4, 6.5
SV2	23209	rainfed farming, extensive grazing, veld products	+	–	±	±	±	+	+	±	+	+	improved RF + AF, improved grazing and VP	6.1, 6.3, 6.4, 6.5
SV3	597	extensive grazing	–	–	–	–	–	–	+	–	–	+	improved grazing	6.4

LAND USES:

RF Rainfed arable farming
MF Molapo farming
HG Home vegetable garden
BN Backyard nursery and orchard
BK Beekeeping
AF Agroforestry
CC Carrying capacity
DC Duck/chicken pen
VP Veld product exploitation
WU Wildlife utilization

SUITABILITY RATINGS:

\+ suitable
± marginally suitable
– not suitable

7.4 Implementation strategy

Before implementation of this plan can take place, a last consultation should take place with the farming community or their representatives, leaving room for feedback and modifications of the final recommendations.

Anticipating the implementation of the plan a matrix has been produced, which shows the main actors, activities and beneficiaries and a proposed time frame, see Table 60. The implementation matrix should be consulted in conjunction with the outcome of the evaluation procedures of Chapter 6 and the conclusions and recommendations formulated in Chapter 7.

As the RAO and the SVO are the main clients of this land use plan, they should take up the responsibility to guarantee the input and achievements of their support staff and extension workers.

For an effective implementation of the plan key actors should include the achievements expected from them in their annual workplans, and budget time and money for inputs accordingly.

List of abbreviations used in Table 60

Planning level

DA Office - District Agricultural Office
DWNP - Department of Wildlife and National Parks
MoA - Ministry of Agriculture
NWDC - North West District Council
RA Office - Regional Agricultural Office
RVO - Regional Veterinary Office

Actors

AD - Agricultural Demonstrator
ALUP - Agricultural Land Use Planner
BAMB - Botswana Agricultural Marketing Board
BKO - Beekeeping Officer
BMC - Botswana Meat Commission
CPO - Crop Production Officer
CS - Cartography Section MoA
DAHP - Department of Animal Health and Production
DAO - District Agricultural Officer
DCPF - Director of Crop Production and Forestry
EC - Extension Coordinator
FO - Forestry Officer
HO - Horticulture Officer
MO - Marketing Officer
MS - Marketing Section
LAC - Livestock Advisory Centre
RAO - Regional Agricultural Officer
RE - Range Ecologist
RES - Range Ecology Section
SCO - Soil Conservation Officer
SS - Soil Surveyor
SVO - Senior Veterinary Officer
VA - Veterinary Assistant
VDC - Village Development Committee

Timing

asap - as soon as possible

Table 60. Implementation matrix

LEVEL	ACTOR(S)	ACTIVITY	BENEFICIARIES	TIMING
IMPROVED RAINFED ARABLE FARMING				
Chanoga AEA	AD	1. Extension on use of kraal manure	W1, W2, R1	October/November, before cropping season
		2. Extension on ploughing in of crop residue	P2, W1, W2, R1	May/June, after cropping season
		3. Extension on the use of inorganic fertilizer	W1, W2, R1	October/November, before cropping season
		4. Extension on soil suitability	P1, P2, W1, W2, R1	July/September, during off season
		5. Extension on improved crop husbandry practices	P1, P2, W1, W2, R1	All year round
		6. Extension on alternative management practices	W2, R1	July/September, during off season
		7. Extension on alternative crops	P1, P2, W1, W2, R1	July/September, during off season
DA Office	DAO	1. To support Ads in transfer of technology; liaise with extension staff RA Office and MoA, concerning extension recommendations and packages	ADs	All year round
RA Office	SS	1. Extension on soil suitability, kraal manure, inorganic fertilizer	P1, P2, W1, W2, R1	July/September, during off season
	CPO	2. Extension on improved crop husbandry, alternative management practices and alternative crops	P1, P2, W1, W2, R1	All year round
	ALUP	3. Organize workshop for ADs/Vas in map reading and production of land use map of extension areas	ADs, VAs	July/September
	RAO	4. Liaise with MoA and coordinate technology transfer	ADs, all farmers	All year round
	MO	5. Assist in improving marketing situation	P1, P2, W1, W2, R1	May/September, after harvesting
MoA	EC/CS	1. Equip AD/VA offices with base maps	ADs, VAs, all farmers	asap
	MoA	2. Improve transport situation AD/VA	ADs, VAs, all farmers	asap
	EC	3. Development of extension packages	ADs, VAs, all farmers	asap
	EC	4. Development of creative extension transfer methodologies	ADs, VAs, all farmers	asap
	EC	5. Reintroduction of the farmers' record card	ADs, VAs, all farmers	asap
	EC/CS	6. Harmonize boundaries of AD and VA extension areas	ADs, VAs, all farmers	asap
	DCPF	7. Restructure ALDEP Phase II packages	P1, P2, W1, W2, R1	asap
	DCPF	8. Restructure future arable Drought Relief programmes	P1, P2, W1, W2, R1	asap
	MoA	9. Creation of a farmers' credit/saving scheme	P1, P2, W1, W2, R1	asap
	MS/BAMB	10. Improve marketing situation / BAMB	P1, P2, W1, W2, R1	asap
	MoA	11. Sensitize private sector to stock supplies	P1, P2, W1, W2, R1	asap
IMPROVED MOLAPO FARMING				
Chanoga AEA	AD	1. Extension on improved crop husbandry practices	W1, W2, R1	All year round
RA Office	CPO	1. Extension on improved crop husbandry practices	W1, W2, R1	All year round
HORTICULTURAL, BEEKEEPING AND AGROFORESTRY PROJECTS				
Chanoga AEA	AD	1. Promote home vegetable gardening and find trial farmers	P1, P2, W1, W2, R1	July/September
		2. Promote backyard nurseries, orchards and find trial farmers	P1, P2, W1, W2, R1	July/September
		3. Promote beekeeping and find trial farmers	P1, P2, W1, W2, R1	July/September
		4. Monitoring of on-farm agroforestry (wind break) trials	W2, R1	All year round

RA Office	HO FO/HO BKO FO/SCO	1. Design home gardens and supply inputs/advice to trial farmers 2. Design backyard nurseries, orchards and supply inputs/advice to trial farmers 3. Design apiaries and supply inputs/advice to trial farmers 4. Design and monitoring of agroforestry (wind break) trials	P1, P2, W1, W2, R1 P1, P2, W1, W2, R1 P1, P2, W1, W2, R1 W2, R1	July/September July/September July/September All year round
IMPROVED LIVESTOCK PRODUCTION SYSTEMS				
Chanoga AEA	VA	1. Extension on controlled breeding, supplementary feed and increased offtake rates 2. Facilitate formation of water development/fencing groups 3. Promote duck/chicken production	all livestock owners small cattle owners all farmers	asap asap asap
RAO	ALUP/RE	1. Range assessment and grazing plan for after CBPP	all livestock owners	asap
RVO	SVO	1. Assist in formation of water development/fencing groups 2. Assist in construction of cattle dip tank 3. Facilitate reopening of Makalamabedi AI Camp	small cattle owners small cattle owners all cattle owners	asap asap asap
MoA	DAHP/LAC DAHP DAHP MS/BMC	1. Restructure services LAC 2. Promote spreading of extension messages 3. Consult with land Board regarding borehole certificates 4. Improve cattle and smallstock marketing channels	all livestock owners all livestock owners small cattle owners all livestock owners	asap asap asap asap
IMPROVED USE OF VELD PRODUCTS				
Chanoga AEA	AD	1. Increase awareness about importance of veld products 2. Investigate interest in mopane coppicing project (with VDC)	P1, P2, W1 all farmers	July/September July/September
RA Office	RE RAO/RE RAO/MO FO	1. Collect baseline data on present veld products 2. Initiate awareness campaign 3. Facilitate in formation veld product marketing board (pilot project) 4. Assist in setup and monitoring of mopane coppicing project	all farmers all farmers all farmers all farmers	All year round February/June February/June All year round
MoA	RES	1. Development of sustainable harvesting techniques 2. Set sustainable quota 3. Coordinate formation veld product marketing board (national)	all farmers all farmers all farmers	All year round April/May February/June
IMPROVED WILDLIFE UTILIZATION				
DWNP	DWNP	1. Optimize use of NG35	all farmers	November/March
IMPROVED FARMERS' WELL BEING				
RA Office	CPO	1. Promote purchase of ALDEP water catchment tanks	all farmers	July/September
NWDC	NWDC	1. Improve water supply in settlements 2. Support with start of new income generating activities 3. Upgrading of feeder roads 4. Investigate possibility for electricity and telephone connections and explore feasibility of use of alternative power sources	all farmers all farmers all farmers all farmers	asap asap asap asap
RVO	SVO	1. Assist farmer syndicates in drilling and equipping of boreholes	all livestock owners	asap

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APPENDIX I SOIL TYPES AND EXTENT BY LAND UNIT

LAND UNIT (LU)	SOIL TYPES FAO 1990	SOIL TYPES SLB 1990	AREA (ha)	AREA % of LU	AREA % of AEA
AS1	CLplu	A9b	221	13.9	0.3
	FLear	A24a	843	53.0	1.1
	GLe	A31a	21	1.3	0.0
	LPe	x 1)	90	5.7	0.1
	LVgcal	A7b	110	6.9	0.1
	LVh	A14a	305	19.2	0.4
		subtotal:	1590	100	2
AS2	ARheu	A40	5361	64.9	6.8
	ARheu-ARl	A40-A41	2479	30.0	3.2
	ARl	A41	426	5.1	0.5
		subtotal:	8266	100	10.6
AS3	CLhar	L11	415	14.7	0.5
	CLpar	A21a	1075	38.0	1.4
	CLplu	A9b	292	10.3	0.4
	LVhar	A15a	1047	37.0	1.3
		subtotal:	2829	100	3.6
AS4	CLpluephycal	C5b	569	100.0	0.7
LS1	ARheu	L16, LS17d	3457	100.0	4.4
LS2	CLpar	L12	221	24.1	0.3
	CLplu	L24b	144	15.8	0.2
	CLpluephycal	C5b	167	18.2	0.2
	LVhar	L22a	384	41.9	0.5
		subtotal:	916	100	1.2
LS3	LPe	C3	168	100.0	0.2
SV1	ARheu	S17	24834	67.7	31.7
	ARheu-ARo	S17-S3	11860	32.3	15.1
		subtotal:	36694	100	46.9
SV2	ARl	S5b	3212	13.8	4.1
	CLlsoar	L24c	2459	10.6	3.1
	CLpar	L12b	2949	12.7	3.8
	CLplu	L24b	325	1.4	0.4
	LVhar	L22a	14264	61.5	18.2
		subtotal:	23209	100	29.6
SV3	CLl	L24	529	88.6	0.7
	CLlsoar	L24c	68	11.4	0.1
		subtotal:	597	100	0.8

1) LPe, soil x in land unit AS1, not recognised in SLB 1990 – Revised Soil Legend of Botswana 1990.

N.B.: See Tables 3 and 9 for an explanation of the Soil Type and Land Unit codes.

APPENDIX II OCCURRENCE OF SPECIES PER STRATUM IN VEGETATION UNITS

VEGETATION UNIT		V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
STRUCTURE		GR	GR/FL	GR/FL+SAO	SS - SSD	SSD	SSD - SAD	SA	SA - SAD	SAD	SAD	W
NUMBER of OBSERVATIONS		1	1	2	7	2	4	1	4	5	2	2
STRATUM	SPECIES	OCCURRENCE (COVER PERCENTAGE)										
TREE > 3 m	Aan				1,2,3	2	1		1	1,2,5		
	Ael									3,4		
	Aer				1,2,13	3	1,2,4	2	2,3,21	3,3,3,4,4	1	
	Ale						1	1	3,21	4,13		
	Ame							1	1,2	3		
	Ato			5	0.5,2		2,2,9	2	1,4			5,16
	Bal				0.5		2		1,1,3,7	2,2,3		
	Bdl											5
	Cco									1		
	Che											3
	Cim				3		1,1					3
	Cmg											5
	Cmo				1,1	5					14,15	
	Lne				2		2			1,1,3,3		
	Tpr							10		1		4
	Tse									1		
UPPER BUSH 1.5–3 m	Aan				1,1	1	1			1,1,1		
	Ael									4		
	Aer				2,7	2	1,1,2	1	1,4	1,1,1,2,5		
	Afl									1		
	Ale						2	1	4	4,7		
	Ame			9			1	2	1,3	1,1,9		
	Ato			3	0.5		2	2	1	1		9
	Bal				1		1,2		3			
	Bpe				1,7							
	Cab											5
	Cal						3,5,5					
	Cco				2,2					1		
	Che						1					4
	Cmo					4	5				12,14	
	Cpy						3					
	Dci				6				1	2		2
	Gfl									1		
	Grw				1,6,18	6	4,5		13	5		
	Lne				1,3		2			1		
	Mhe			1								
	Mse											2
	Rbr						1					
	Tpr							5		1		
	Tse				1,2,8					7		
	Xam											4
	Xca				1							
LOWER BUSH <1.5 m	Aan				3							
	Ael									5		
	Aer				1,3,4	4			5			
	Afl				1	1,2				1	1	
	Ahe						1					
	Ale									1		
	Ame							9	6	2,4		
	Ato			1			1	10	1	2		7
	Bpe				5,7,21,35	1					7	
	Cal						9,12,19,48					
	Cap				4							
	Cco				2,4							
	Che				1							
	Cmo					4,28	3,4				2,16	
	Cpy				1,1,2,3,3		3,7			2,11	2	
	Dci				5		1,3	1	4	7	1	
	Gfl				6,8	7	5		4,4	1	4	
	Grw				5,9,13	8	5,6,12		19	1,8,28		
	Lne				1,5,9,11					1	1,4	
	Mhe			4								
	Rbr					7	5,6			18		
	Rte				1,1,1,2	1			5	1,1,2		
	Ssc											35
	Tpr									1		
	Tse				1,6,7,11					2	4	
	Xam									2		
	Xca				2							
HERB UNDER CANOPY	Cci				20		10					
	Cvi				5		1					5
	Dae				1	10						
	Dmi				2,3,5,7,7,30	10		7.5		10		
	Ebi									20		5
	Ele				1,4,4,5,38		10		3		1	
	Eri					35						10
	Esp									10		
	Pan				10				50	20		35
	Pde											5
	Pma							7.5		10		
	Spa				4,4	10				10,10,60		
	Sun				15,15	5,10		15			1,2	
	Utr				1		19	7.5	4	10		
HERB AWAY CANOPY	Ast									1		
	Bni									2		
	Cci				50		8					
	Cda		25					7.5				5
	Cvi								2			3
	Dae				5,20		2			1	3	
	Dmi				2,2,10	5		7.5	2,20	1		
	Ece				3		3,5					
	Ele				2,3,3,4		2	5	3		10	
	Eri					5			2	1		3
	Esp			4,5			0.5					
	Jsp		25									
	Pan								20			
	Pau	85										
	Psq				4,10							
	Rre				5							
	Sed		3									
	Spa		4		2,3,3,5,5,20	10	0.5,5		8	2,10,15,70		4
	Sun				8,40	20,40	12,15,20			2	7,25	
	Tbe							2.5	2			
	Utr			4,5	10	10,15	2,5,10	7.5	1,2,4	2		5

APPENDIX III SOIL TYPES AND EXTENT BY VEGETATION UNIT

VEGETATION UNIT (VU)	SOIL TYPES		AREA		
	FAO 1990	SLB 1990	(ha)	% of VU	% of AEA
V1	FLear	A24a	259	100.0	0.3
V2	CLplu	A9b	62	9.3	0.1
	FLear	A24a	584	87.6	0.7
	GLe	A31a	21	3.1	0.0
		subtotal:	667	100	0.8
V3	CLlsoar	L24c	18	5.0	0.0
	CLpluephypcal	C5b	341	95.0	0.5
		subtotal:	359	100	0.5
V4	ARheu	LS17d, S17	23785	63.0	30.4
	ARheu–ARo	S17–S3	8367	22.2	10.7
	ARl	S5b	9	0.0	0.0
	CLl	L24	232	0.6	0.3
	CLlsoar	L24c	496	1.3	0.6
	CLpar	L12b	2014	5.4	2.6
	CLplu	L24b	242	0.6	0.3
	LVhar	L22a	2599	6.9	3.3
		subtotal:	37744	100	48.2
V5	ARheu	S17	56	3.7	0.1
	ARheu–ARo	S17–S3	110	7.4	0.1
	ARl	S5b	37	2.5	0.1
	LVhar	L22a	1290	86.4	1.6
		subtotal:	1493	100	1.9
V6	ARheu	S17	84	1.9	0.1
	ARheu–ARo	S17–S3	544	12.1	0.7
	ARl	S5b	2829	63.1	3.6
	CLl	L24	151	3.4	0.2
	CLlsoar	L24c	105	2.3	0.1
	CLpar	L12(b)	309	6.9	0.4
	CLplu	L24b	144	3.2	0.2
	LPe	C3	168	3.8	0.2
	LVhar	L22a	147	3.3	0.2
		subtotal:	4481	100	5.7
V7	ARheu	A40	495	30.1	0.7
	CLhar	L11	415	25.2	0.5
	CLpar	A21a	304	18.5	0.4
	CLplu	A9b	27	1.6	0.0
	CLpluephycal	C5b	167	10.1	0.2
	LVhar	A15a	238	14.5	0.3
		subtotal:	1646	100	2.1
V8	ARheu	A40, (L)S17(d)	3011	17.6	3.9
	ARheu–ARo	S17–S3	268	1.6	0.3
	CLl	L24	146	0.9	0.2
	CLlsoar	L24c	1908	11.2	2.4
	CLpar	A21a, L12(b)	1464	8.6	1.9
	CLplu	A9b, L24b	312	1.8	0.4
	CLpluephypcal	C5b	228	1.3	0.3
	LVhar	A15a, L22a	9744	57.0	12.4
		subtotal:	17079	100	21.8
V9	ARheu	A40, L16, S17	5947	54.4	7.6
	ARheu–ARl	A40–A41	2418	22.1	3.1
	ARheu–ARo	S17–S3	267	2.4	0.4
	ARl	A41	426	3.9	0.5
	CLpar	A21a, L12	67	0.6	0.1
	CLplu	A9b	30	0.3	0.0
	LPe	x 1)	54	0.5	0.1
	LVgcal	A7b	110	1.0	0.1
	LVh	A14a	40	0.4	0.1
	LVhar	A15a, L22a	1570	14.4	2.0
		subtotal:	10929	100	14.0
V10	ARheu–ARo	S17–S3	2306	85.1	3.0
	ARl	S5b	337	12.4	0.4
	LVhar	L22a	67	2.5	0.1
		subtotal:	2710	100	3.5
V11	ARheu	A40	274	29.5	0.4
	ARheu–ARl	A40–A41	61	6.6	0.1
	CLpar	A21a	87	9.4	0.1
	CLplu	A9b	165	17.8	0.2
	LPe	x 1)	36	3.9	0.0
	LVh	A14a	265	28.5	0.3
	LVhar	A15a	40	4.3	0.1
		subtotal:	928	100	1.2

1) LPe, soil x in vegetation units V9 and V11, not recognized in SLB 1990 – Revised Soil Legend of Botswana.

N.B.: See Tables 3 and 6 for an explanation of the Soil Type and Vegetation Unit codes.

APPENDIX IV VEGETATION UNITS AND SOIL TYPES AND EXTENT BY LAND UNIT

LAND UNIT (LU)	VEGETATION UNIT (VU)	SOIL TYPE	AREA (ha)	AREA % of LU	AREA % of AEA
AS1	V1	FLear	259	16.3	0.3
	V2	CLplu	62	3.9	
		FLear	584	36.8	
		GLe	21	1.3	
		subtotal:	667	42.0	0.8
	V9	LPe	54	3.4	
		LVgcal	110	6.9	
		LVh	40	2.5	
		subtotal:	204	12.8	0.3
	V11	CLplu	159	10.0	
		LPe	36	2.2	
		LVh	265	16.7	
		subtotal:	460	28.9	0.6
		total:	1590	100	2
AS2	V7	ARheu	495	6.0	0.6
	V8	ARheu	1219	14.8	1.6
	V9	ARheu	3373	40.8	
		ARheu-ARl	2418	29.2	
		ARl	426	5.2	
		subtotal:	6217	75.2	8.0
	V11	ARheu	274	3.3	
		ARheu-ARl	61	0.7	
		subtotal:	335	4.0	0.4
		total:	8266	100	10.6
AS3	V7	CLhar	415	14.7	
		CLpar	304	10.7	
		CLplu	27	1.0	
		LVhar	238	8.4	
		subtotal:	984	34.8	1.3
	V8	CLpar	639	22.6	
		CLplu	229	8.1	
		LVhar	623	22.0	
		subtotal:	1491	52.7	1.9
	V9	CLpar	45	1.6	
		CLplu	30	1.0	
		LVhar	146	5.2	
		subtotal:	221	7.8	0.3
	V11	CLpar	87	3.1	
		CLplu	6	0.2	
		LVhar	40	1.4	
		subtotal:	133	4.7	0.2
		total:	2829	100	3.6
AS4	V3	CLpluephypcal	341	59.9	0.4
	V7	CLpluephypcal	167	29.4	0.2
	V8	CLpluephypcal	61	10.7	0.1
		total:	569	100	0.7
LS1	V4	ARheu	2661	77.0	3.4
	V8	ARheu	42	1.2	0.0
	V9	ARheu	754	21.8	1.0
		total:	3457	100	4.4
LS2	V6	CLpar	38	4.1	
		CLplu	144	15.7	
		subtotal:	182	19.9	0.2
	V8	CLpar	161	17.6	
		CLpluephypcal	167	18.2	
		LVhar	16	1.7	
		subtotal:	344	37.5	0.5
	V9	CLpar	22	2.4	
		LVhar	368	40.2	
		subtotal:	390	42.6	0.5
		total:	916	100	1.2
LS3	V6	LPe	168	100	0.2
SV1	V4	ARheu	21124	57.6	
		ARheu-ARo	8367	22.8	
		subtotal:	29491	80.4	37.7
	V5	ARheu	56	0.1	
		ARheu-ARo	110	0.3	
		subtotal:	166	0.4	0.2
	V6	ARheu	84	0.2	
		ARheu-ARo	544	1.5	
		subtotal:	628	1.7	0.8
	V8	ARheu	1750	4.8	
		ARheu-ARo	266	0.7	
		subtotal:	2016	5.5	2.6
	V9	ARheu	1820	5.0	
		ARheu-ARo	267	0.7	
		subtotal:	2087	5.7	2.7
	V10	ARheu-ARo	2306	6.3	2.9
		total:	36694	100	46.9
SV2	V4	ARl	9	0.0	
		CLlsoar	496	2.1	
		CLpar	2014	8.7	
		CLplu	242	1.1	
		LVhar	2599	11.2	
		subtotal:	5360	23.1	6.8
	V5	ARl	37	0.2	
		LVhar	1290	5.5	
		subtotal:	1327	5.7	1.7
	V6	ARl	2829	12.2	
		CLlsoar	86	0.4	
		CLpar	271	1.2	
		LVhar	147	0.6	
		subtotal:	3333	14.4	4.3
	V8	CLlsoar	1877	8.1	
		CLpar	664	2.9	
		CLplu	83	0.3	
		LVhar	9105	39.2	
		subtotal:	11729	50.5	15.0
	V9	LVhar	1056	4.6	1.3
	V10	ARl	337	1.4	
		LVhar	67	0.3	
		subtotal:	404	1.7	0.5
		total:	23209	100	29.6
SV3	V3	CLlsoar	18	3.0	0.0
	V4	CLl	232	38.9	0.3
	V6	CLl	151	25.3	
		CLlsoar	19	3.2	
		subtotal:	170	28.5	0.2
	V8	CLl	146	24.5	
		CLlsoar	31	5.2	
		subtotal:	177	29.6	0.3
		total:	597	100	0.8

N.B.: See Tables 3, 6 and 9 for an explanation of the Soil Type, Vegetation Unit and Land Unit codes.

FIELD DOCUMENTS

produced by FAO/UNDP/GOB project BOT/91/001
Land Use Planning for Sustainable Agricultural Development

1. Some notes on the identification and socio-economic analysis of different farmer classes, 1993.

2. Agricultural Land Use Plan for Former Freehold Farms 25/77 and 27/77 NQ (North-East District), 1994.

3. Agricultural Land Use Plan for Ratholo Agricultural Extension Area (Central Region), 1995.

4. Guidelines for the Use of CYSLAMB. Applications for Agricultural Land Use Planning and Extension in Botswana, 1994.

5. Guidelines for the Use of ILWIS, 1994.

6. Agricultural Land Use Plan for Lesoma Village Area (Chobe District), 1995.

7. Flood recession farming (molapo farming) in the Chobe Enclave (Chobe District), 1995.

8. On-farm Crop Trials Cropping Season 1994/95. Results and Evaluation, 1995.

9. Agricultural Land use Plan for Moroka Agricultural Extension Area (North-East District), 1995.

10. Guidelines for Agricultural Land Use Planning in Botswana, 1996.

11. Agricultural Land Use Plan for Moshupa-South Agricultural Extension Area (Southern Region), 1995.

12. Agricultural Land Use Plan for Chanoga Agricultural Extension Area (Maun Region), 1996.

13. Guidelines for Land Allocation along the River Banks in the Maun Area, 1995.

Copies of these documents can be obtained from the Department of Crop Production & Forestry, Division of Land Utilization, Ministry of Agriculture, Private Bag 003 Gaborone.