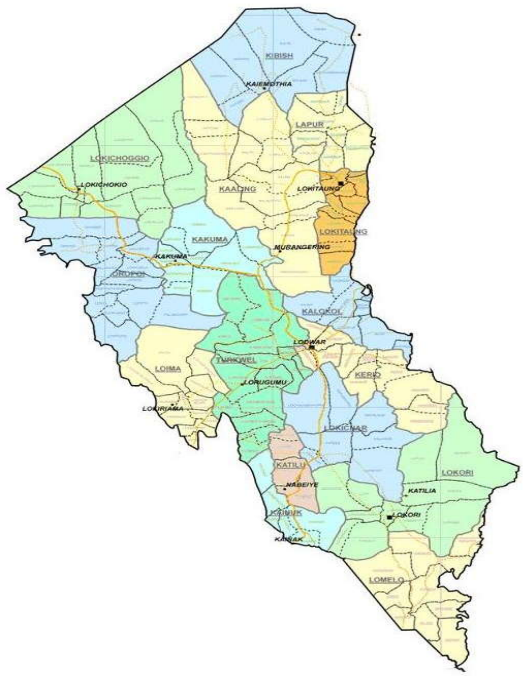
Livestock development and climate change in Turkana district, Kenya



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1. Background

For many years African livestock production was seen as a poor investment for development. Today, however, a new ‘livestock revolution’, fuelled by massive growth in global demand for food of animal origin, is foreseen (Delgado et al. 1999). According to Scoones and Wolmer (2006) the livestock sector in the developing world is growing at a rate of up to 7 per cent per annum, much faster than the agricultural sector as a whole and by 2020 it is predicted to become the most important sub-sector in terms of added value. They argue that Africa can, and should capitalise on its enormous wealth in livestock and gain access to new markets opening up. The New Partnership for African Development (NEPAD, 2005) similarly makes a case for investments in rural infrastructure to underpin market access and the sustainable development of livestock resources. More specific assessments of the African livestock sector have highlighted the need for a pro-poor livestock development focus (ILRI, 2000; Perry et al., 2002; Scoones and Wolmer, 2006) – relating to the increasing emphasis on the role of greater market access for agricultural products from the developing world as a pathway out of poverty (Perry et al, 2005).

VSF Belgium shares this vision and is therefore implementing a Livestock Development Program in Turkana District. The overall goal of the project is to improve livelihoods of vulnerable pastoral communities in the Arid and Semi Arid Lands (ASAL) through enhanced livestock production, increased access to water, improved marketing opportunities and peace building initiatives, through developing partnerships and strengthening local capacities.

Specific objectives of the programme are to:

- Increase livestock productivity in vulnerable pastoralist communities in ASAL locations.
- Increase access to potable water for pastoralists and their livestock in pasture potential areas of central and southern region of Turkana District
- Improve the economic returns of pastoralist communities through increased marketing of livestock and livestock products
- Reduce the natural resource based conflict amongst pastoralist community in the Karamoja Cluster through peace initiatives
- Promote viable and sustainable indigenous organizations, indigenous structures and local institutions, through partnership and capacity building.

On the other hand, it is becoming widely accepted that changes in atmospheric composition are likely to alter temperatures, precipitation patterns, extreme events and other aspects of climate on which the natural environment and human systems depend (IPCC, 2001).

The main purpose of the study presented here is to shed some light using simple and aggregated methods on the following question:

In view of the expected climate change, is there also a long-term perspective for livestock development in the area, i.e. will the Turkana ecosystem be able to sustain livestock production during the next few decades? In our search for an answer to this question, we looked at the current pressure on the environment, tried to interpolate the predicted climate change to the Turkana District scale and started exploring some of the possible impacts of climate change on the environment and the people depending on it. Due to the simplistic nature of the analyses performed, we consider these figures to be indicative only.

This study goes hand in hand with another one focussing on market access and opportunities.

2. Introduction

2.1 Turkana, an arid pastoralist district in the northwest of Kenya

Turkana District occupies the North Western part of Kenya, to the West of Lake Turkana. Most of the District consists of low lying plains with isolated mountains and hill ranges. The altitude is about 900m at the foot of the escarpment marking the Ugandan border to the west, and then falls to 369m to the shores of Lake Turkana in the east. The altitude of the mountain ranges are between 1,500 and 1800 metres in the east reaching the peak at Loima, which forms undulating hills for a stretch of some 65 Km^2. The isolated mountains are mainly found in the central area with plains around Lodwar and more specifically the Lotikippi Plains in the north. In the south-east, the Suguta valley follows a tectonic trough bordering the Samburu uplands.

The Lake is situated in the eastern side of the District, with fishing being the major activity in the Lake. The District has several rivers with the major ones being Turkwel and Kerio, both originating in the highlands to the south. These rivers are the most important in the District and the only perennial ones. The other rivers are seasonal.

Turkana District is an arid district, the temperatures range between 24°C to and 38°C with a mean of 30°C. There are two rainfall seasons. The long rains normally occur between March and July and the short rains between October and November. The rainfall ranges between 120mm and 500mm per year; the western parts and areas of higher elevation in the District receive more rainfall (see annex 1 for maps). The rainfall is erratic in distribution and timing. The dryer the area, the more unreliable the rain is. The intra-year coefficient of variation is more than 50% throughout the District, with peaks of 75% and more in the driest western areas (Hijmans et al., 2004). The data collected by Ebei and Oba (2007) show the recurrent nature of droughts in the district. It emerged from their study that the most devastating droughts have occurred about every ten years (1952, 1960, 1970, 1980, 1990, and 2000) (see Table 1). While the 1940s and 1950s were normal years, droughts became more common from the late 1970s. Drought in the Turkana District is a common occurrence and has been accepted by most Turkana pastoralists as a normal part of life.

Table 1: Major drought events in Turkana District and mean mortality rates associated with these droughts at household level for the period 1952 to 2003.

Drought's local name(s)	Year	Mortality rate (%)[1]
Lotiira	1952	61
Namotor	1960	55
Kimududu/kibekbek	1970	54
Kiyoto atang'aa/Lopiar	1980	65
Lokwakoyo/Akalkal	1990	53
Logara/epompo	2000	63

[1] ***Mean mortality rate of small stock***
Source: Ebei and Oba (2007)

The length of growing period is defined as the period during which available water exceeds the amount needed by plants for survival. This excess is used for plant growth. Most of the District has a length of growing period of less than 60 days and is thus unsuitable for cropping. In summary, the climate in Turkana District is very harsh and it doesn't sustain rain-fed cropping. According to Blench (2000), approximately 70% of the human population inhabiting Turkana are nomadic or semi-nomadic, depending on pastoralist livestock production for their survival. Five species of livestock are managed: cattle, camels, donkeys, goats and sheep.
The myriad challenges faced by the pastoralists in Turkana are summarised in the marketing report, they've also been added to this report as annex 5.

2.2 Climate change is expected

Hulme et al. (2001) show that climate change in Africa is not simply a phenomenon of the future, but one of the relatively recent past. The continent is warmer than it was 100 years ago, and the rate of warming is about 0.5 degrees per century. Hulme et al. (2001) also illustrate the large regional differences that exist in rainfall variability. The Sahel, for example, has displayed considerable multi-decadal variability with recent drying. East Africa appears to have a relatively stable rainfall regime, although there is some evidence of long-term wetting.

Future climate is of course not known with any certainty, but there is a range of possibilities, due to both incomplete understanding of the climate system and the inherent unpredictability of climate. While this distribution is unknown, sensible guesses can be made as to its magnitude and shape, and choices can always then be made so as to sample a reasonable part of its range (Hulme et al., 2001).

As stated in the assessment by the Intergovernmental Panel on Climate Change (IPCC, 2001), this climate change is expected to present serious challenges (and sometimes opportunities) to food security. Food and feed production is influenced by the availability of water, nutrients, as well as by temperature. As stated in the assessment by IPCC (2001), increases in temperature could open new areas to cultivation, but they also increase the risk of heat or drought stress in other areas. Livestock are all susceptible to heat stress and drought. Some plant and animal species may be seriously affected or even disappear because they might be unable to adapt. The assessment further outlines that water availability is another component of food security and that its quantity and distribution depend to a large extent on rainfall and evapo-transpiration, which are both affected in a changing climate. Climate change is only one of the components of a set of global-scale environmental changes affecting ecosystems. Global change includes changes in the composition of the atmosphere such as the observed increases in the concentration of CO_2, methane, and CFCs. These changes in atmospheric composition may have direct impacts upon vegetation, with or without climate change. Global change also includes changes in land use which are driven by economic, demographic, and social forces (Sala et al, 1996).

2.3 The impacts of climate variability and climate change on livestock production

The productivity of livestock will as well directly as indirectly be influenced by changes in the climate. In order to investigate the feasibility for livestock development under the predicted climate changes, it is therefore essential to assess these linkages. A summary of some potential direct impacts is given in section 1.4.1. Section 1.4.2 highlights some possible indirect impacts of climate change on the livestock production.

2.3.1 Direct impacts

Domestic livestock, like other animals, have a 'climate envelope' in which they perform optimally. Beyond the thermal optimum, meat and milk production declines. There is limited potential for extending this limit through breeding. Field (2005) notes that when the temperature limits are reached, cattle stop eating, movement such as walking to pasture and water are hindered, breeding is interrupted, and milk production drops. The heat-induced loss of appetite can also delay the time an animal takes to reach market weight by a year or more. A regional livestock study by ICRC (2005) compares the ideal environment for cattle with the conditions in the arid lands (see table 2).

Table 2: Comparison between the arid lands and the ideal environment for cattle

	Arid conditions	Ideal Environment for cattle
Mean annual rainfall (mm)	100-300	More than 500
Temperature range (degree C)	25-40	13-18
Relative humidity (%)	40-60	60-70
Wind speed (kph)	20-50	5-30
Solar radiation	High	Medium
Annual potential evaporation (mm)	1,500–2,000	500-1,000

We can see that already huge differences from the optimal conditions occur. The current rainfall and temperature ranges in Turkana, 120-500mm and 24-38 ^{o}C, are equally far from ideal. It is clear that climate change, through changing temperature and precipitation regimes, might close this gap or further alter this difference, depending on the direction of the change.

2.3.2 Indirect impacts

According to the IPCC (2001), major impacts of climate change on livestock production in the rangelands are mediated through changes in net primary production of pasture. They state that increased variability of rainfall and temperature is likely to affect the phenology of plant and animal species. It also would affect animal numbers and feeding behaviour and would be critical for some pests and diseases and availability of forage for livestock and other mammals. Species composition changes could also occur. Regional climate change and elevated CO_2 may change the balance from more herbaceous species (grasses and herbs) to more woody species (mainly shrubs), subsequently affecting productivity, decomposition, and fire frequency of the system, as well as forage quality. As a result of possible changes in plant community composition, structure, and forage quality the net primary production and therefore feed availability will change.

Although the classical concepts of animal carrying capacity may not be very useful as a local management tool due to the high inter-annual variability, they remain valued as indicators of animal production when they are applied over long periods and large areas. Many researchers have demonstrated a strong link between long-term, large-area herbivore biomass and mean precipitation in African rangelands. Changes in livestock numbers could therefore be directly proportional to changes in annual precipitation (IPCC, 2001).

The causal chain between rainfall and animal numbers passes through grass production, which in arid and semi-arid environments is approximately linearly related to rainfall. Le Houerou (1983) defined the slope of this relationship as the Rain-Use Efficiency (RUE), i.e. the quotient of annual primary production by annual rainfall. The RUE is the amount of dry matter produced in a given area over a given period of time per unit of rain, usually expressed in kg DM/ha/year/mm. The RUE is, amongst others, a function of soil nutrient availability, CO_2 concentration, and plant composition. It is closely controlled by an ecosystem's functioning and thus very sensitive to range condition and depletion status (Le Houerou, 2006). According to O'Connor et al. (2001) up to 63% of the variation in primary production can be explained by precipitation and species composition.

Varnmakhasti et al (1995) show that temporal variation in RUE occurs as a consequence of changes in the vegetation. Spatial variation in RUE occurs as a consequence of, for instance, differences in average annual rainfall and vegetation type between sites (Huxman et al, 2004).

Hein and De Ridder (2006) noted a substantial variation in RUE between years at any given location irrespective of any degradation process. They list 3 main causes:

1. At low rainfall, relatively more water is lost through evapo-transpiration, leaving less water available for plants. Consequently, RUE decreases at low rainfall
2. At high rainfall, RUE decreases because ecosystem productivity becomes limited by nutrients rather than water
3. Variation in species composition between years

Therefore, for a given site, RUE as a function of annual rainfall follows a quadratic curve. RUE is highest for annual rainfall close to the average rainfall, and relatively low for both low and high rainfall. With a change in rainfall pattern, one could therefore expect to observe lower RUEs.

Livestock distribution and productivity could also be influenced via changes in the distribution of vector-borne livestock diseases, such as trypanosomiasis, the tick-born East Coast Fever and Rift Valley Fever.

2.4 Vulnerability of the pastoralists

Domestic livestock play a central role in Turkana. Their value goes beyond the production of meat; it is based on the full set of services they supply (milk, meat, blood, hides), their asset value as a form of savings, and their cultural symbolism. It would be difficult to abandon pastoralism in the event that it becomes climatically, environmentally, or economically unviable (ILRI, 2006).

High levels of vulnerability and low adaptive capacity have been linked to factors such as a high reliance on natural resources, limited ability to adapt financially and institutionally, high poverty rates and a lack of safety nets (Thomas and Twyman, 2005). The very nature of the pastoralist lifestyle in Turkana is highly dependent on natural resources, i.e. on the availability and accessibility of water and pasture for the animals. According to Ebei et al. (2007b) the severity of droughts and their impact on livestock production translate into reduced purchasing power of pastoral households. They further found that the household livestock per capita (TLU) for the period 1987 to 1997 increased in the late 1980s, but crashed in the following years. Overall, the average TLU per capita was far below the recommended values for subsistence requirements (4.0-7.1 TLU per capita). Also the poverty rate calculated by CBS and ILRI (1999) in Turkana is very high with 61% of the population living below the poverty line in 1999. We can conclude that the pastoralists in Turkana are highly vulnerable to the expected climate change.

Nevertheless, droughts are a part of the natural cycle in Turkana and are for the pastoralists an accepted pattern of life (Field, 2005). As is quite extensively explained in the related market access and opportunities study, the traditional strategy of pastoralists is to move to areas with higher rainfall, and then return to traditionally drier areas when the rains arrive and both pasture and browse is renewed. It is further reiterated that several factors are severely compromising these long-distance movements of livestock, i.e. establishment of national frontiers, increased frequency of droughts, growing human and livestock numbers, insecurity and encroachment into traditional dry season pasture by agro-pastoralism.

The animal population pays its toll during droughts in Turkana. The magnitude of livestock loss was estimated by Sanford and Habtu (2002). They write that pastoralists may lose up to 50% of their livestock during a drought. Using average mortality rates of 50%, 30%, 24% and 17% for cattle, sheep, goat and camel herds respectively, and computer models based on Dahl and Hjort's herd growth theory, they estimated a recovery period of respectively 10, 2, 1.5 and 4 years. Obviously, such long recovery periods leave the pastoralist vulnerable to recurrent droughts. The frequencies and severities of droughts hinder recovery, as the herd growth is disrupted by 'new' droughts before the recovery phase is completed (Oba, 2001; Angassa and Oba, 2007). Ebei et al. (2007a) report that sheep and cattle are more sensitive to droughts than other livestock species. By comparison, goats, donkeys and camels were more resistant to drought-induced stresses. While Field (2005) notes that camel are drought-resistant and small stock breed rapidly so recover quickly, and therefore cattle are considered most vulnerable. For that reason, most pastoralists prepare for droughts by keeping herds with multiple species.

Other examples of coping strategies implemented by the pastoralists, include: slaughtering livestock and preserving the meat, the preservation of grazing areas for times of extreme drought, division of large herds into smaller units and species, stock loaning between relatives and friends, collection of wild fruits and bartered cereals, and begging for food (ILRI, 2006).

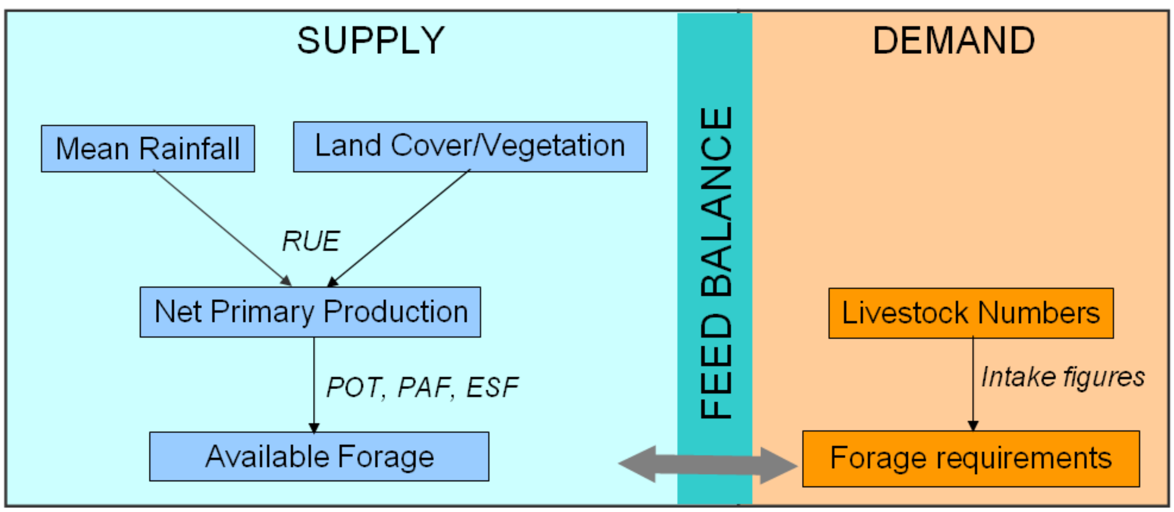
3. Methodology

We undertook three steps in our analysis, with the final aim of getting a feel for possible changes in potential livestock production in the Turkana Ecosystem due to climate changes.
We started off by taking a look at the current situation. Based on mean rainfall figures, an estimate of the Rain Use Efficiency (RUE) of the Turkana rangelands and official government livestock statistics, we estimated the feed balance. This gave us a good idea about the current livestock pressure on the system and the implications on the livestock productivity. We then went ahead and had a look at the expected climate change. Different scenarios were downscaled and future rainfall and temperature regimes obtained. In the third and last step, we tried to link the previous two. On the basis of the new rainfall figures, we ran different scenarios with changing RUE values and explored possible effects on the feed balance. The next paragraphs explain in more detail each of these steps.

3.1 Estimating the Feed Balance

In order to get a better idea of the existing pressure on the natural resources, the current feed balance was estimated as summarised in figure 3. We basically compared the available forage with the forage requirements. The method used here, builds extensively on the methods and data from the GTZ, Range Management Handbook.

Figure 3: Estimating the feed balance



3.1.1 The supply side – estimating the available forage

Several factors have an influence on the primary production of an ecosystem. These include soil, rainfall, density of herbaceous cover, species composition and the land use / management (e.g. fire regime, stocking rates). According to Le Houerou (personal communication, 2006), a rain use efficiency (RUE) of 2.5 to 3 kg DM/ha/mm/year is describing the type, condition and productivity of the Turkana ecosystem quite well. An average of 2.75 kg DM/ha/mm/year was used with exclusion of water bodies, national reserves and build-up areas. We extracted these land cover classes from the Africover (2000) dataset and assigned them a zero primary production. A Geographical Information System was used to combine land cover, Worldclim rainfall data for the year 2000 (Hijmans et al. 2004) and RUE spatially and come up with annual and monthly maps of net primary production.

Annual NPP = RUE * MAP

Monthly NPP = RUE / 365 * N * MMP

with NPP = Net Primary Production (kg DM)
RUE = Rain Use Efficiency (kg DM/ha/mm/year)
MAP = Mean Annual Precipitation (mm)
MMP = Mean Monthly Precipitation (mm)
N = Number of days in the month

Not all the net primary production is readily available forage for livestock, though. Three adjustment factors were used to reduce the net primary production to actual available forage:

- Permissible off-take (POT): This is expressed as a percentage of the total biomass produced. Off-take below or at recommended levels ensures that overgrazing, degradation of vegetation and long-term changes in the botanical composition of the pastures are avoided.
- Permanent Accessibility Factor (PAF): This is the rate of accessibility of the land (by livestock). It is derived from an estimate of the proportion of land of different accessibility and has a value between 0 and 1 for very sever to no restrictions respectively.
- Erosion Status Factor (ESF): An expression of the erosion status by which the permissible off-take is adjusted. Different erosion hazards include: no degradation = 1, slight = 0.75, moderate = 0.5, severe = 0.25.

We obtained the above three factors from the GTZ range management handbook spatial database. This dataset dates back to 1994 and hasn't been updated since. In a validation workshop held in Lodwar in November 2006, the maps of rainfall, POT, PAF and ESF were presented to and verified by the participants. There was a consensus that all 4 factors were realistically representing the situation in the district in the year 2000.

POT, PAF and ESF were originally collected on the level of rangeland management units. We converted them to the same resolution as the net primary production layers and used a GIS again to produce available forage maps using the following formula:

Available Forage = NPP * POT * PAF * ESF

3.1.2 The demand side – estimating the forage requirements

We obtained official livestock estimates from the Ministry of Agriculture. The RUMINANT model (Herrero et al 1999, 2002) was used to establish intake figures for cattle, sheep, goat and camels. RUMINANT is a widely validated model to assess responses to nutrients by ruminants. It predicts intake and performance from the knowledge of animal characteristics and the composition of feeds. It is based on similar concepts as the model of Illius and Gordon (1991). The predicted intake figures multiplied by the livestock numbers gave us an estimate of the forage requirements. The nutrient requirements are expressed in kg DM/animal/day. Taking into account the number of days in a month, monthly as well as yearly total feed requirements were calculated.

We didn't take into account intra-annual fluctuations of livestock figures (through births, diseases, slaughter and marketing), nor the herd structure. We rather assumed the total livestock figures to be constant within a year and to all represent fully-grown animals. These assumptions most probably caused an overestimation of the actual feed requirements.

3.1.3 Feed balance

Using a GIS system, we totalled the forage supply over the whole District. We then estimated the feed balance by simply subtracting the forage requirements from the available forage. This was done on an annual as well as monthly basis. This is obviously a gross simplification but it gives us an idea of the magnitude of the feed deficits in the region.

3.2 Climate Change modelling

The methods used here are described in more detail in Thornton et al. (2006). We used the data set TYN SC 2.0 for looking at different scenarios of climate change to 2050 (Mitchell et al., 2004). The variables used from this data set were the diurnal temperature range, precipitation and average daily temperature on a monthly basis. In all, there are 20 climate change scenarios in the complete data set, made up of all permutations of five Atmosphere-Ocean General Circulation Models (CGMs) and four different greenhouse gas emission scenarios (IPCC, 2001). In these scenarios, known as the SRES (Special Report on Emissions Scenarios) scenarios, the "A" scenarios have more of an emphasis on economic growth, the "B" scenarios on environmental protection. The "1" scenarios assume more globalisation, the "2" scenarios more regionalization (IPCC, 2000).

There are considerable differences between SRES scenarios and between the different GCMs, in terms of projected changes in temperatures, rainfall and length of growing periods in regions of Africa. These differences are in general difficult to interpret. Here, we have concentrated on a subset of the GCMs and scenarios. For the GCMs, we used models from the Hadley Centre, UK, and the Max Planck Institute for Meteorology, Germany, named HadCM3 and ECHam4 respectively, as these have reasonable ability to represent observed climate conditions at a regional level (McHugh, 2005). In addition, ECHam4 is a "wet" model – the rainfall differences projected are relatively large, compared with the drier HadCM3 model. All SRES scenarios project temperature increases, and most of the range of projected temperature increases to 2100 is covered by two scenarios, A1F1 and B1 (IPCC, 2001), and so the results reported here concentrate on these.

For the analysis, we started with the 1-km interpolated climate grid for the globe named WorldCLIM (Hijmans et al., 2004), which we took to be representative of current climatic conditions (most of the data cover the period 1960-1990). We reassembled the climate grid to a resolution of 10 arc-minutes to make the analysis programmes run faster. We then prepared similar climate grid files, but for each combination of the two GCMs and two SRES scenarios selected, and separately for the years 2020 and 2050 – hence a total of 8 projections where made. Details of the algorithm can be found in Jones and Gladkov (1999) and Jones and Thornton (2000).

To calculate length of growing period, we proceeded using the method of Jones (1986). While for changes in weather variability, we generated a data layer of the coefficient of variation (CV) of annual rainfall using downscaled GCM outputs and the MarkSim weather generator (for more details see Jones and Thornton, 2000). We cannot yet develop surfaces of rainfall CV for future possible climates in any meaningful way, so current rainfall CV and changes in rainfall amounts were used as proxies for future conditions. This is a serious limitation of the current study. IPCC (2001) noted that increases in mean precipitation are likely to be associated with increases in variability, and precipitation variability is likely to decrease in areas of reduced mean precipitation. Many studies have shown tendencies for inter-annual rainfall variation to increase. In many regions, including parts of Africa, inter-annual climatic variability is strongly related to El Niño - Southern Oscillation ENSO, and thus will be affected by changes in ENSO behaviour (Hanson et al., 2006).

3.3 Estimating the impacts

As described in section 2.2, we down-scaled projected precipitation data to Turkana district. There are, however, too many unknown factors for us to be able to predict future net primary production and potential livestock production with any level of certainty. Firstly, there is the uncertainty in predicted precipitation. The scale of the climate models is unsuitable to incorporate some of the landscape features in a relatively small area like Turkana. Also, we don't know enough about the changes in vegetation and its response to changing rainfall figures to be able to make an estimate about the future RUE factor of the Turkana ecosystem. The literature suggests decreasing RUE values with changing rainfall patterns, though (Huxman, 2004; Hein and De Ridder, 2006). We therefore used the output of the different climate scenarios with several reduced RUEs to estimate possible future primary production.

4. Results and discussion

4.1 Feed balance

The present total annual primary production for Turkana District was estimated to reach almost 8 million MT. As the maps in annex 3 and Table 3 below show, there is considerable spatial as well as temporal variation in this production. This variation follows the rainfall pattern very closely, with higher production in the Western and Northern regions of the District and peaks just after the rains.

Introduction of permissible off-take, accessibility and erosion status reduced the available forage to less than 10% of the actual production. The estimated available forage ranges from 0 to 550 kg DM/ha/year, averaging out to about 116 kg/ha/year. The northern areas are the only ones with more than 200 kg dry matter available per hectare. As can be seen on the monthly available production and available forage maps in annex 3, there are several months with very low forage production throughout the District. Even the high productive areas in the North and the West of the District produce less than 100 kg DM/ha in the dry months of December, January and February. That's why it is so important to move animals around and reserve some areas as exclusive dry season grazing.

Table 3: The supply side (MT DM/month) – the year 2000

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Primary production (MT)	166,837	437,996	918,804	1,638,351	935,466	444,001	763,362	534,217	346,001	461,351	809,747	340,380
Available forage (MT)	15,862	36,614	75,449	144,386	81,038	36,861	64,662	43,363	26,791	39,269	68,811	28,617

Table 4 shows the annual feed requirements for the reported number of animals in the year 2000. It is clear that besides the intake figures, the number of animals play an important role in these total feed requirements. Although camels require more feed than any other species, their total requirements only rank third because they are fewer, while the relatively small goats end up requiring more than any other animal species, because they are so many.

Table 4: Livestock numbers and requirements

	Numbers	Intake (kg DM/day)	Feed Requirement (MT DM/year)
Cattle	176,000	4.5	289,080
Sheep	813,000	0.6	178,047
Goats	1,626,000	0.6	356,094
Camels	138,000	5	251,850

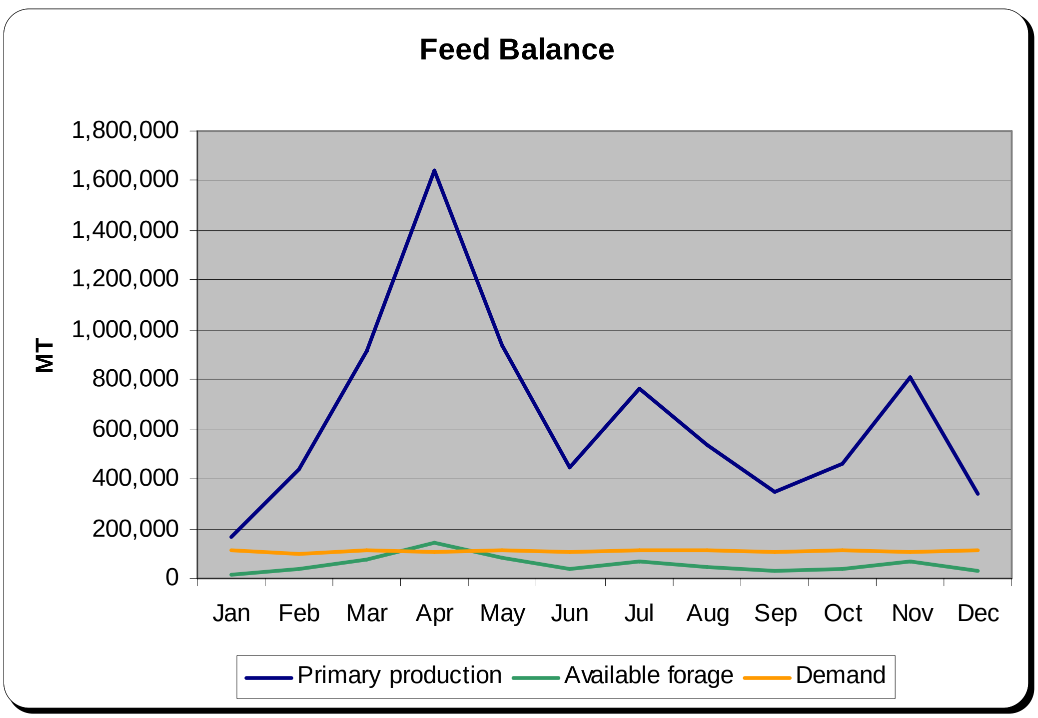
In Table 5, we show these annual figures broken down into monthly requirements. All the species compete for feed resources, so we added them up and estimated the total livestock feed requirement in the District.

Table 5: Total feed requirements (MT DM/month)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cattle	27,007	24,394	27,007	26,136	27,007	26,136	27,007	27,007	26,136	27,007	26,136	27,007
Sheep	22,985	20,761	22,985	22,244	22,985	22,244	22,985	22,985	22,244	22,985	22,244	22,985
Goat	46,088	41,628	46,088	44,601	46,088	44,601	46,088	46,088	44,601	46,088	44,601	46,088
Camel	28,371	25,626	28,371	27,456	28,371	27,456	28,371	28,371	27,456	28,371	27,456	28,371
Total	124,483	112,436	124,483	120,467	124,483	120,467	124,483	124,483	120,467	124,483	120,467	124,483

The comparison of feed supply and demand is shown in Figure 4. We can see a feed deficit throughout most of the year, the exception being the wet month of April. With the reduced international mobility and quite high insecurity in the area, we can assume that most animals depend on the feed production within the District, although some might move out, especially in the dry season and definitely during extended droughts. Even if we had overestimated the feed requirements by 35%, we would still see a feed deficit in 8 out of the 12 months. A lot of animals must therefore have a production that is far below their potential or the number of animals must be exceeding the permissible stocking rate, and thereby most probably causing land degradation.

Figure 4: Comparison of feed supply and demand in Turkana district in the year 2000



4.2 Climate change

The first 2 maps in Annex 4 show projected changes in the length of the growing period (LGP) from 2000 to 2050, from downscaled outputs of the ECHam4 GCM for scenarios A1F1 and B1 and of the HadCM3 GCM for scenarios A1F1 and B1. Following IPCC (2001) map legends, these changes were classified into five classes: losses in LGP of > 20% ("large" losses); of 5-20% ("moderate" losses); no change (± 5% change); gains of 5-20% ("moderate" gains); and gains of >20% ("large" gains). Various points can be made about these maps. First, it should be noted that some of the large losses and large gains are located in areas with a LGP less than 60 days, i.e. in highly marginal areas for cropping. Second, there is considerable variability in results arising from the different scenarios, and there is also variability in results arising from the different General Circulation Models (GCMs) used. Third, if anything could be generalized about these different maps, it is that under the range of these SRES scenarios and the GCMs used, many parts of sub-Saharan Africa are likely to experience a decrease in the length of growing period, and in some areas, the decreases may be severe. To put it another way, projected increases in temperature and projected changes in rainfall patterns and amount (increases in rainfall amounts are projected in many areas) combine to suggest that growing periods will decrease in many places. There are also a few areas where the combination of increased temperatures and rainfall changes may lead to an extension of the growing season, and these appear to occur in some of the highland areas.

When zooming in to Turkana (see annex 4 for the maps), we can see that according to all scenarios, the temperatures as well as precipitation is expected to rise in the district. By 2050 temperature increases of up to 5° C and precipitation increases of up to 390 mm/year can be seen. The analysis presented here has several uncertainties associated with it, however, and there are some serious omissions in terms of what we have been able to include. First, there are uncertainties associated with the GCMs themselves and with the science of climate modelling. Second, there are uncertainties related to the SRES scenarios used. Third, there are sources of uncertainty associated with the downscaling techniques used here. Careful downscaling is crucial if the validity of results is to be preserved.

In addition to such technical uncertainties, there are other serious limitations. Most importantly, it is very likely that we are under-estimating the extent of climate-related hazards, because we are not taking into account important extreme events such as droughts and flooding, nor are we directly dealing with the fact that the variability of weather patterns in many places is increasing and with it the probability of extreme events and natural disasters occurring (Kasperson and Dow, 2005).

4.3 Impacts

The projected climatic changes include changing precipitation patterns and amounts and rising temperatures. The literature suggests that this will be associated with increasing magnitude and frequency of extreme events (e.g. IPCC, 2000 & Kasperson and Dow, 2005). The potential direct and indirect impacts of these are briefly covered in the following paragraphs. Climate change is not the only driver of change in the Turkana Ecosystem, however. Others include population growth and associated land use changes, which have not been considered in our analysis/discussion. For example: the study of the encroachment of the traditional dry season grazing areas by agricultural activities and its effects on feed resources; and the changing human and livestock disease burden associated with climate change impacts. Some work has been done on this for Africa, e.g. on Malaria and livestock trypanosomiasis (for example, see Hay et al, 2006; Reid et al., 2000; Thornton et al., 2006b), but much more work needs to be done on these kinds of interactions. Overall, we would judge the results of climate change impacts identified here to be very conservative, and so these results should be seen as indicative only.

4.3.1 Direct Impacts

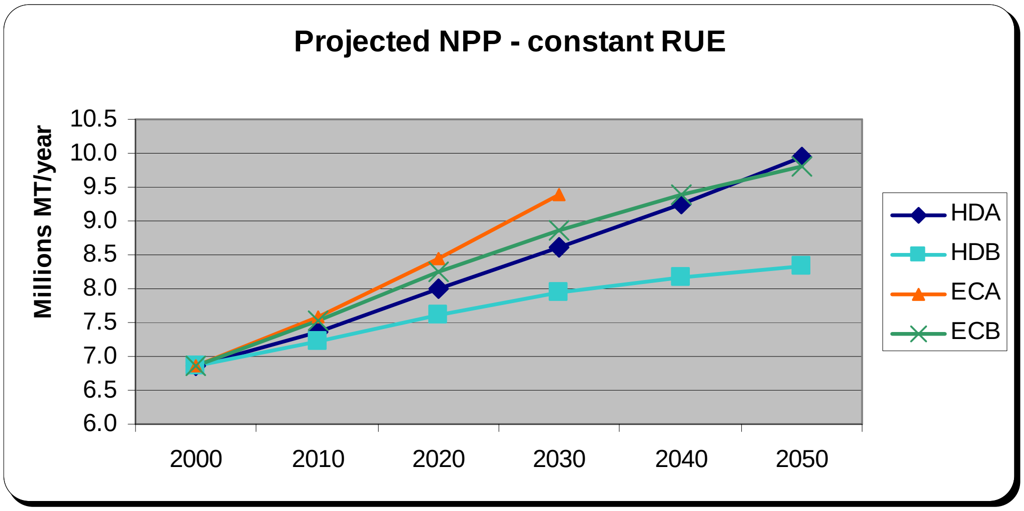
The different scenarios predict an average temperature rise of up to 5° C by 2050. This rise in temperatures will have a direct impact on the productivity of the animals. The ideal temperature for cattle that was presented in Table 2, for example, will be even further exceeded. Growth, production and reproduction will be hampered.

As mentioned in paragraph 3.2, also the magnitude and frequency of droughts and floods is expected to go up. This will undoubtedly result in higher mortality rates and shorter recovery periods, possibly too short for the herds to recover naturally to sustainable sizes.

4.3.2 Indirect impacts

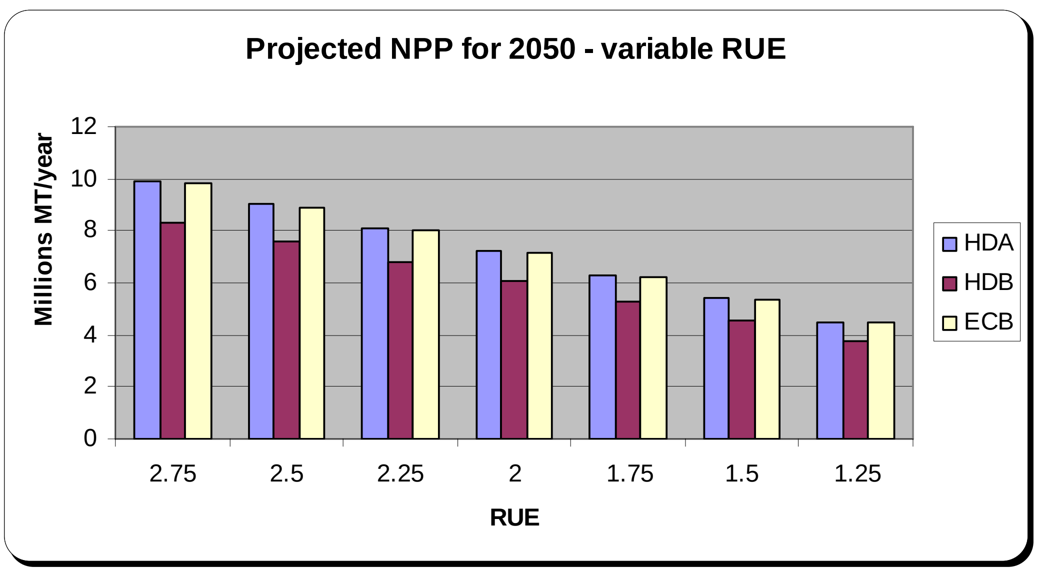
For all the scenarios, increasing rainfall figures can be seen. If we assume constant Rain-Use Efficiency (RUE), the estimated primary production is going up for all scenarios (see figure 4).

Figure 4: Projected NPP at constant RUE



However, the temperatures are predicted to rise too, and through increased evapotranspiration and possible long-term adaptations in species composition, this will most probably reduce the RUE. Figure 5 shows the projected primary production for a range of RUE values for 3 GCM-scenario combinations: HadCM3 GCM scenarios A1F1 and B1 and ECHam4 GCM for scenarios B1.

Figure 5: Projected NPP with variable RUE values



In paragraph 2.2.1 we estimated the present RUE to be an average of 2.75 kg DM/ha/mm/year which resulted in the NPP of 6.8 MT. Without the foreseen changes in RUE, the primary production by 2050 is projected to increase between 21 and 45 percent between 2000 and 2050. At a RUE value reduced to only 2.25, the predicted NPP in 2050 will have reduced slightly according to the HadCM3 GCM scenarios B1, while the other scenarios still predict and increase of almost 20%. A reduction of the RUE to 1.5 causes a projected decrease of NPP by 20 to 34%. Table 6 summarises the projected climate change impacts in terms of temperature, precipitation and NPP under these same scenarios

Table 6: Summary of impacts of different scenarios, time period 2050 compared with baseline in 2000.

	2000	Had CM3-A1F1	**%**	Had CM3-B1F1	**%**	ECHam4 – B1F1	**%**
Temperature (°C)	25	29	***18***	27	***11***	27	***10***
Precipitation (mm)	565	736	***30***	646	***14***	733	***30***
Net Primary Production (millions MT)	6,866,758						
RUE = 2.75		9,933,181	***45***	8,336,900	***21***	9,809,461	***43***
RUE = 2.25		8,127,148	***18***	6,821,100	***-1***	8,025,923	***17***
RUE = 1.75		6,321,115	***-8***	5,305,300	***-23***	6,242,384	***-9***
RUE = 1.25		4,515,082	***-34***	3,789,500	***-45***	4,458,846	***-35***

4.4 Recommendations for management

A recently completed study by the International Committee of the Red Cross (ICRC, 2005) documents and identifies higher level responses to emergencies in livestock owning communities. Though the main emphasis of the study is on emergencies caused by conflict, reference is made to emergencies caused by other factors and a lot of the findings can easily be applied to e.g. flood and drought responses. The study states that most of the livestock dependent systems in the Greater Horn of Africa (e.g. the pastoral system in Turkana District) occur in dis-equilibrium environments. The non-equilibrium approach stresses the importance of stochastic, external disturbances as drivers for ecosystem change (Westoby et al., 1989). In this view, annual rainfall and its variability are the main drivers for the ecosystem productivity. After a drought, a few years with good rainfall can fully restore state and productivity of the plant cover (Ellis and Swift, 1988). Hein and De Ridder (2006) on the other hand suggest that you can't understand the dynamics of semi-arid rangelands without both equilibrium and non-equilibrium approaches. To a certain extend, anthropogenic pressure causes the degradation of the ecosystem. High stocking densities affect the structure and composition of the herbaceous layer, which reduces the productivity of the rangelands and increases the system's vulnerability for drought (Illius and O'Connor, 1999; Hein and De Ridder, 2006). The pressure on the resources has indeed been growing in recent years. Due to the increase in human and livestock population (see the market access and opportunities study and table 7) the pastoralists make more use of the available natural resources in non-drought times, leaving fewer resources to cope with drought conditions.

Table 7: Livestock Population in Turkana District (1993-2005)

	Shoats	*Sheep*	*Goats*	*Cattle*	*Camels*
1993	1,267,880	N/A	N/A	153,350	63,153
1994	2,130,000	N/A	N/A	165,000	94,000
1995	2,566,000	862,000	1,704,000	198,000	112,800
1996	2,683,000	894,333	1,788,667	201,960	114,192
1997	2,750,000	916,667	1,833,333	200,000	115,230
1998	2,750,000	916,667	1,833,333	200,000	115,000
1999	3,252,150	1,084,050	2,168,100	234,420	144,960
2000	2,439,000	813,000	1,626,000	176,000	138,000
2001	2,439,000	813,000	1,626,000	176,000	138,000
2002	2,926,800	975,600	1,951,200	193,600	140,760
2003	2,926,800	975,600	1,951,200	193,600	140,760
2004	3,075,400	1,054,400	2,021,000	197,900	172,400
2005	3,075,400	1,054,400	2,021,000	197,900	172,400

Source: MoL&DF, Turkana District, Annual Reports 1993-2005

The ICRC (2005) regional livestock study makes a case for what is called a tracking strategy (matching animal numbers and feed supply) and/or opportunistic management. This strategy proposes to concentrate interventions to increase productivity when conditions are good, whilst helping the pastoralists to cope during the harsh periods of the cycle. It entails drought contingent programming with different responses and interventions at different stages of an emergency cycle (see figure 1). In accordance with Ebei and Oba (book), early warning systems could then be linked to drought management.

Drought management systems have been promoted strongly by several organisations. A basic drought management system (schematic adapted from Swift et al. shown in figure 2) includes mitigation activities to minimise the impact of drought on production systems and livelihoods, and relief activities for the welfare of those rendered destitute. Longer-term policies for resilience relate closely to, and are necessary for, specific mitigation measures. Thus plans to guarantee drought-time access to specific grazing reserves must be developed in the context of general policy on pastoral land tenure, and the efficacy of emergency marketing interventions may be severely limited by a lack of marketing infrastructure and price distortions in the end-market. Similarly, there are complex interrelations between mitigation measures, relief and rehabilitation (Swift et al., 2002).

Figure 1: The emergency cycle (from Swift et al 2002)

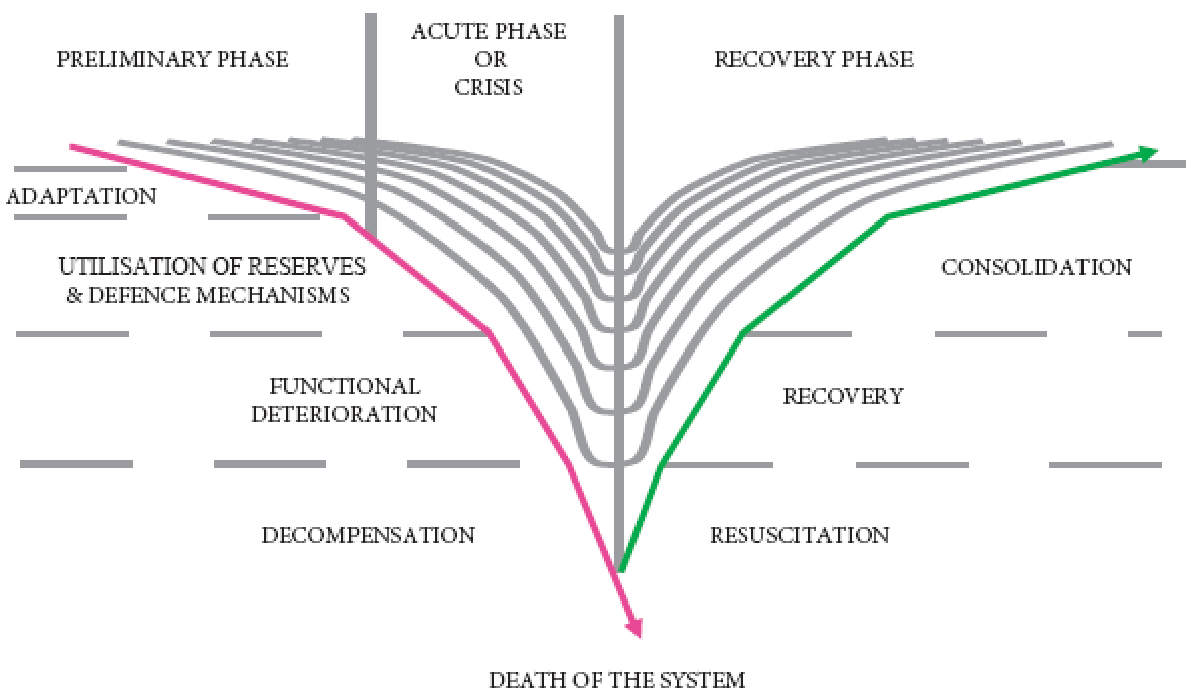
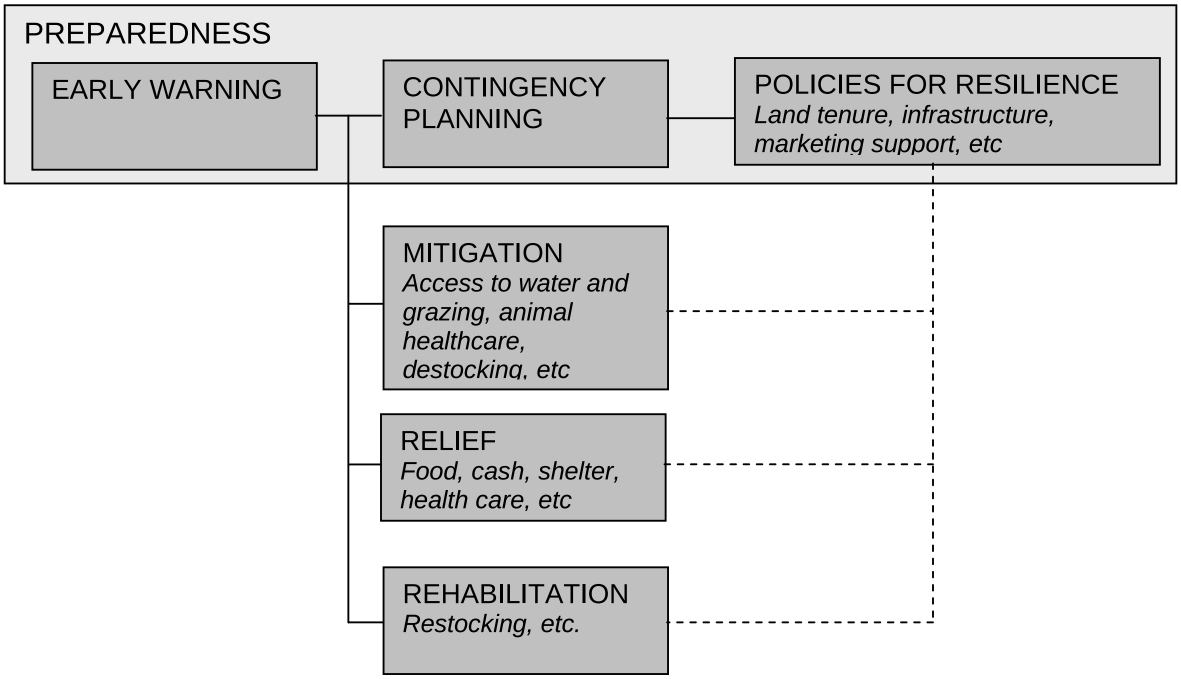


Figure 2: The interrelated components of a drought management system



The Dutch-funded Drought Preparedness Intervention and Recovery Program (DPIRP) and the World Bank-funded Arid Lands Resource Management Project (ALRMP) for example have managed to institutionalise to a degree responses to drought in Northern Kenya. Some policy recommendations made by Swift et al. (2002) include:

- provide early warning and standby capacity
- provide a coordinated approach to planning and implementation of mitigation
- decentralise drought-time decision-making
- seek ways of improving access of pastoral communities to financial services
- livestock marketing interventions are a direct support to livelihoods and should be a key part of contingency plans
- veterinary and water interventions should be a key part of district contingency plans.

Field (2005) adds in his manual for pastoralists and their promoters the availability of drought grazing areas and conflict resolution committees. This coincides with Ebei et al. (2007), who state that in the drought-prone region of Turkana, grazing scarcity and insecurity from raids are the main contributors to livestock losses. Grazing can be secured by making arrangements with neighbouring countries to reduce stress on the herds, while combating raiding through gun-running in the region may require better regional security. Whichever approaches used, the solution for improving food and human security demands approaching the problem from national policy perspectives.

Long-term planning for pastoral production in the Turkana District through drought management requires a high degree of flexibility, which should be aligned with the highly unpredictable climate. According to Ebei and Oba (2007), early warning interventions provided by formal drought EWS in Turkana could be improved by involving the local community in the assessment of prevailing conditions. This will only be possible if EWS researchers access the Tree of Men – a traditional institution in which decisions on migratory patterns are adopted.

In contrast to the relatively well coordinated drought management response in Kenya, there is a lack of an institutional framework to monitor and manage flood disasters. There are weak or no flood disaster management policies in place; it would be useful to include flood preparedness in the emergency planning.

Some of the adaptation options for the rangelands, mentioned by IPCC (2001) and applicable in Turkana, are:

- Landscape management: actions to reduce the destruction of the soil crust and thus land degradation are extremely important. These actions could include adjustment in the time and intensity of grazing.
- Selection of plants and animal species and better stock management are likely to be the most positive management options. Decreased use of marginal lands might be necessary.
- Community participation in decision-making and management, along with public policy, can be favourable and critical issue in implementing some adaptation options. Decisions to be made might include:
    - determinations about appropriate stocking rates, which might require discussion and negotiations among stakeholders, especially because stocking rates might be more social than technically oriented
    - choosing some agro-forestry practices that fulfil local needs without having a negative effect on the environment, especially because many communities rely on fuel wood
    - diversification

5. Conclusion

Even if we might see less dramatic changes in temperature, rainfall and length of growing period than in other areas in Africa, climate change is indeed expected to happen in Turkana. Very little is known about the response of the vegetation to the expected changes; we don't know how the species composition will change and what the resulting Rain Use Efficiency will be. It is clear that more research is needed to understand for example the response of vegetation to changes in climate. In order to better understand the dynamics of the vegetation it is necessary to analyze how the vegetation cover has changed in the past decades as a function of human management and climatic variability. It is only then that we'll be able to predict what the possible impacts of further climate change could be. Also the climate models themselves have their inherent uncertainties and we are at this stage not yet capable to zoom in to a scale that would be useful for more detailed planning in Turkana district. We are therefore not able to predict neither future carrying capacities nor potential livestock production in Turkana with a reasonable level of confidence.

It was, however, established that the pressure on the natural resources is already quite high. On top of that, the recovery period in between extreme events is likely to get even shorter and that the events will get even more extreme. These climate change impacts are compounded with for example population growth and associated land use changes, reduced mobility of pastoralist due to national boundaries and conflict. It will therefore become increasingly important to be prepared for climatic shocks. Some important components include:

- provide early warning and standby capacity
- provide a coordinated approach to planning and implementation of mitigation measures
- decentralise drought-time decision-making
- seek ways of improving access of pastoral communities to financial services
- livestock marketing interventions are a direct support to livelihoods and should be a key part of contingency plans
- veterinary and water interventions should be a key part of district contingency plans
- spatial and temporal planning of livestock densities through dry-season grazing areas and timely off-take

As was mentioned before, there is already a quite well coordinated approach for drought response in Kenya. We believe it is important to strengthen this further in close dialogue with the communities and to also include response to flood situations in this context.

In addition to that it will be crucial to increase the adaptive capacity of the people of Turkana. Given their high vulnerability, steps to strengthen their adaptive and mitigative capacity and to lessen non-climatic stressors could well enhance sustainable development.

There seems to be scope for sensitizing the pastoralist communities with regards to the expected climate changes and the possible need to reduce herd sizes.

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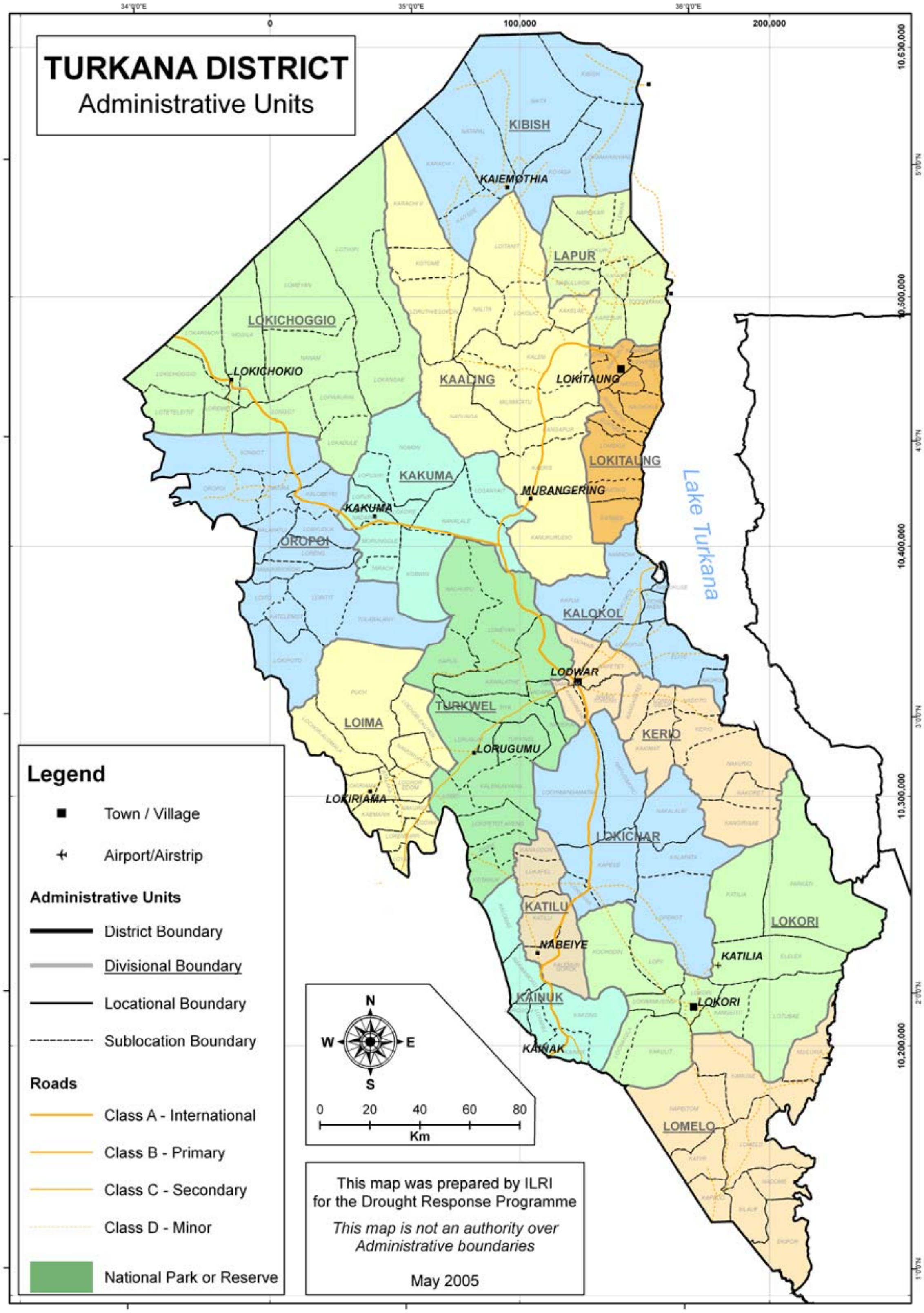
7. ANNEXES

Annex 1: Base maps for Turkana District



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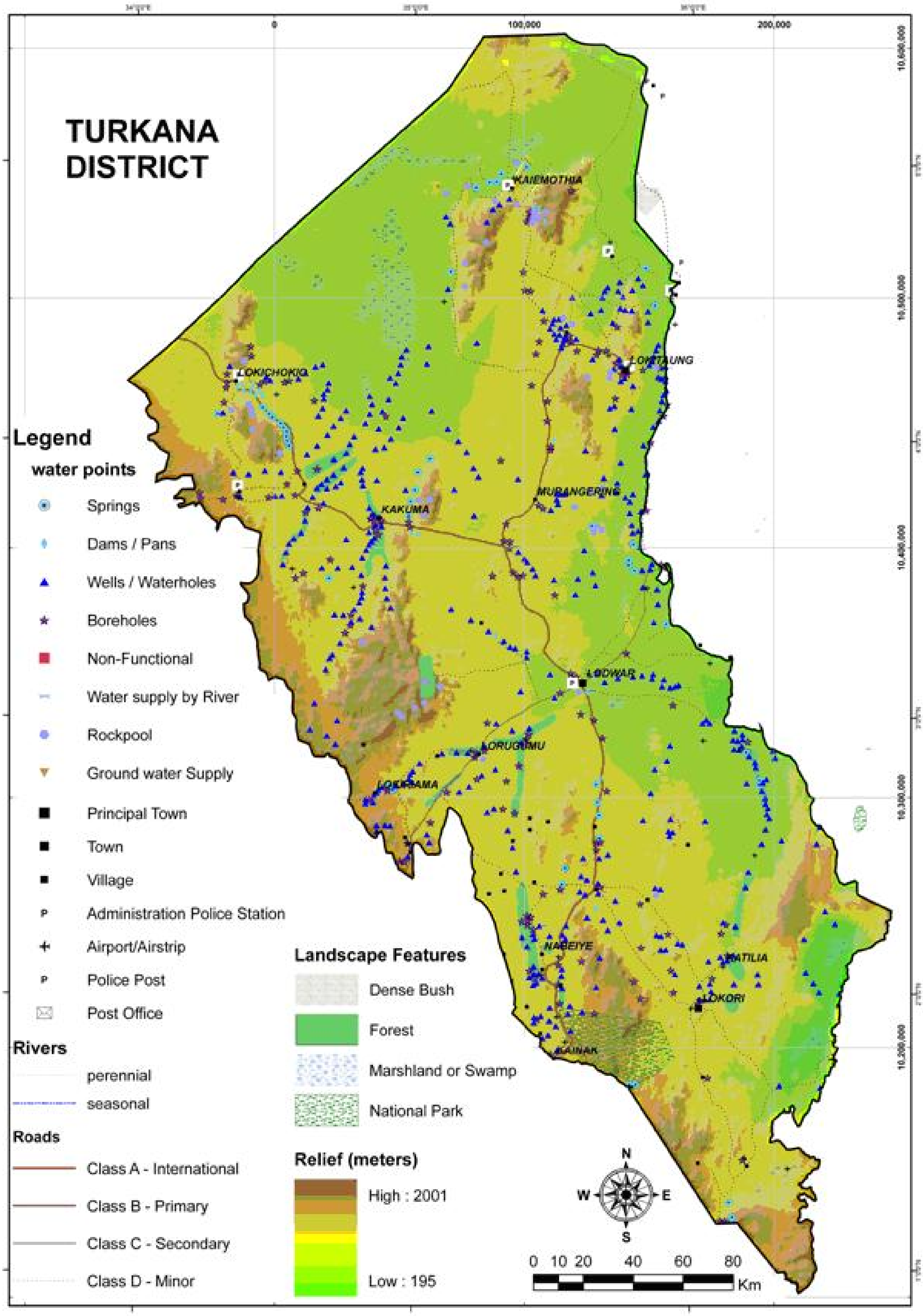

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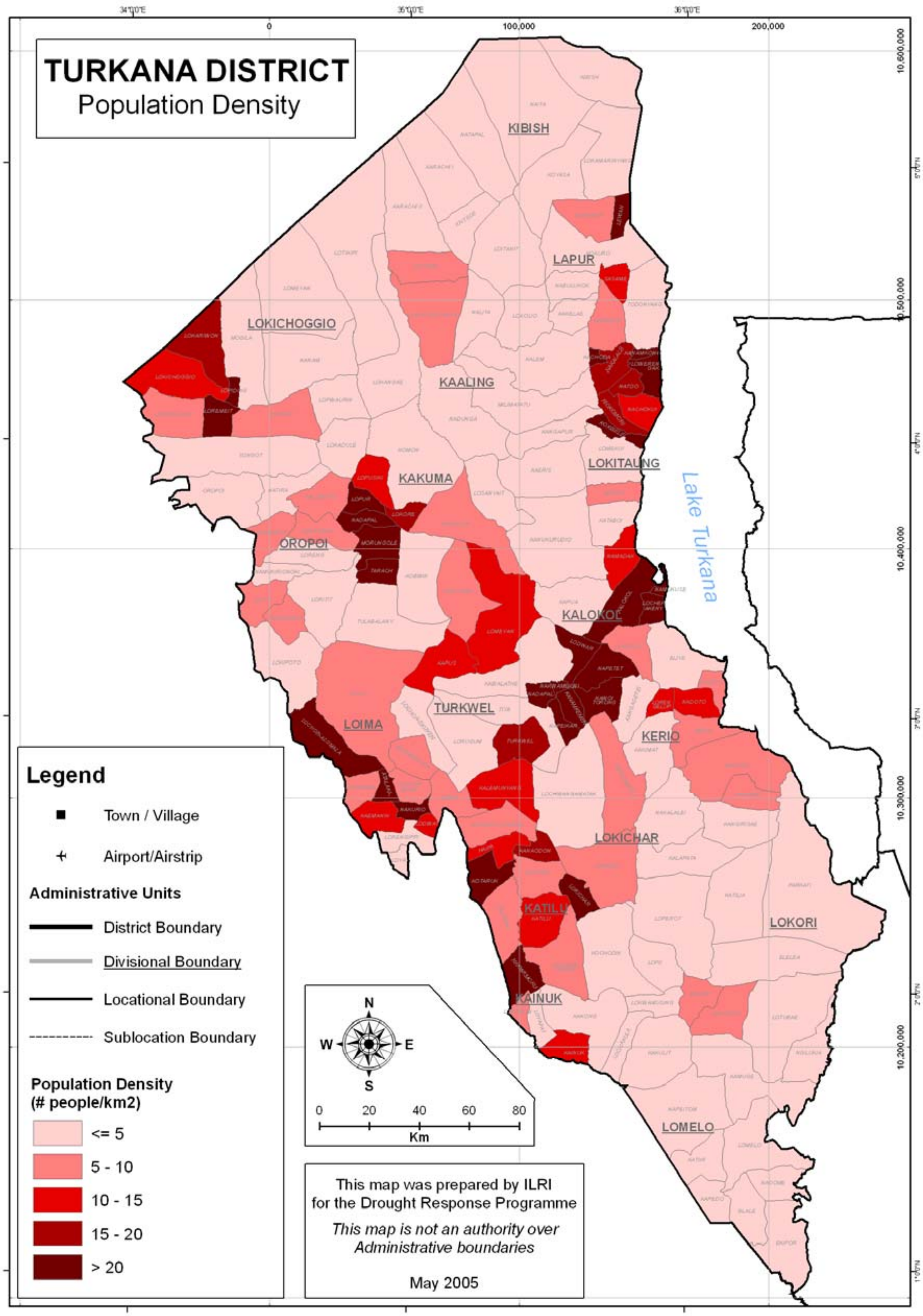

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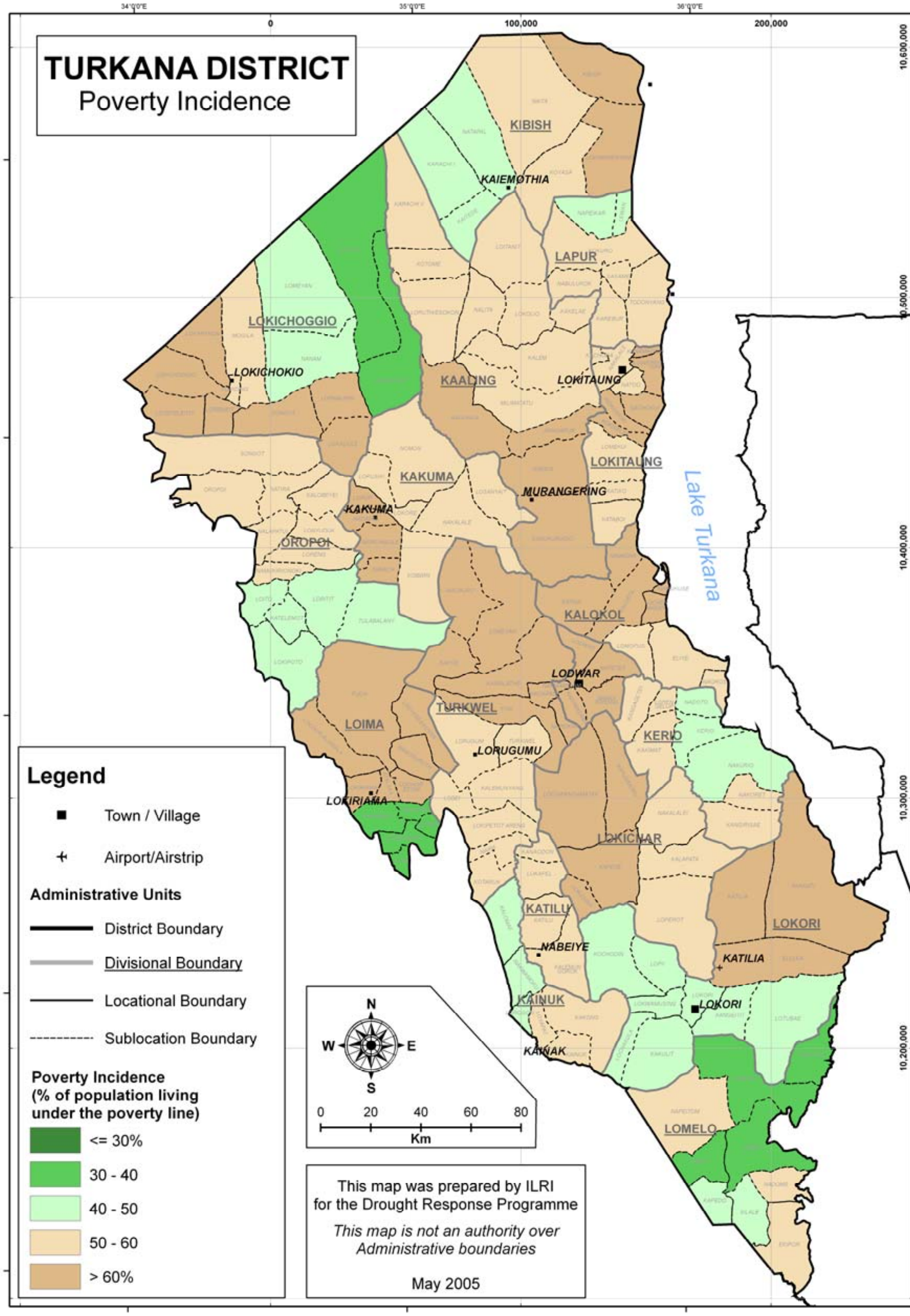

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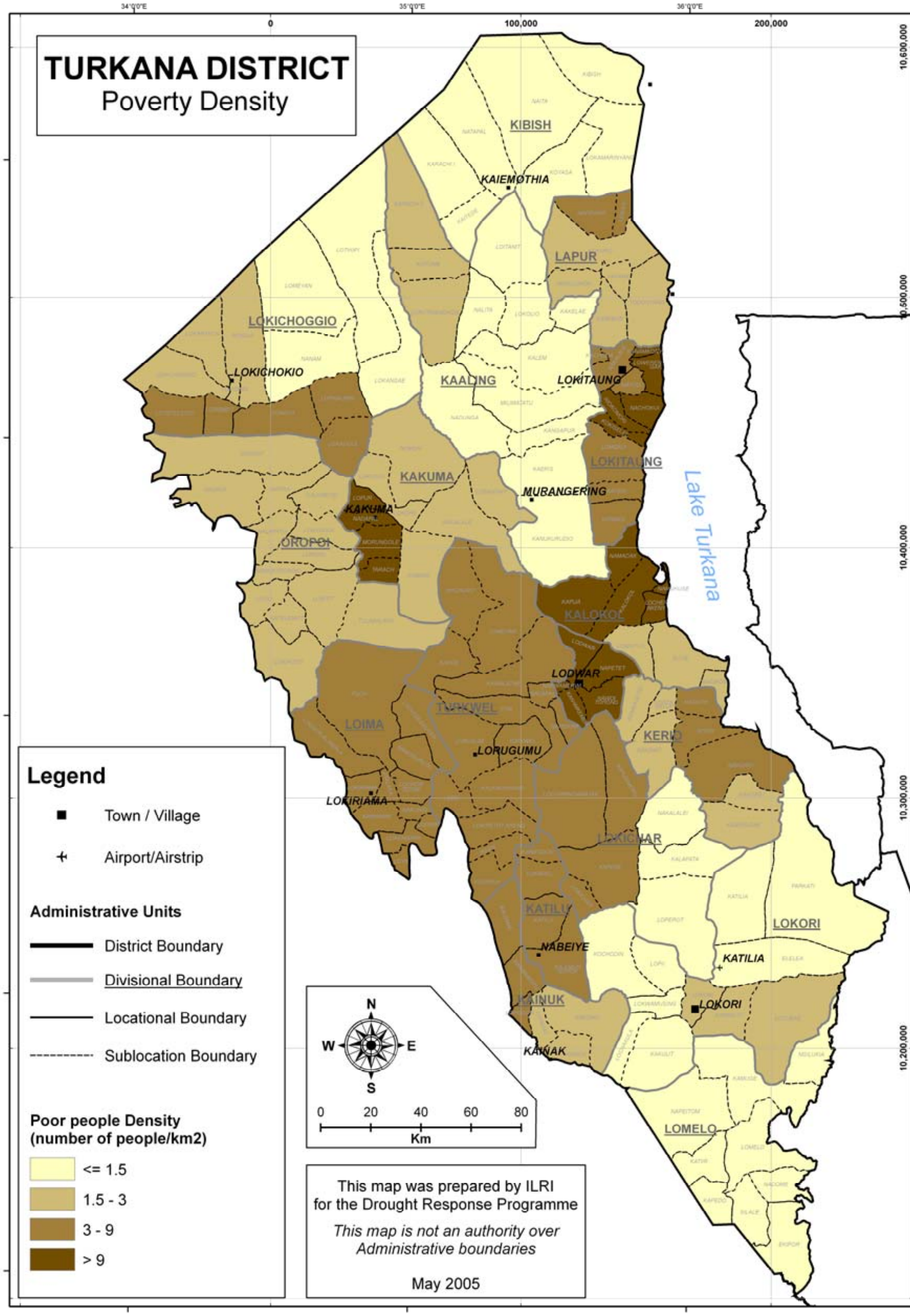

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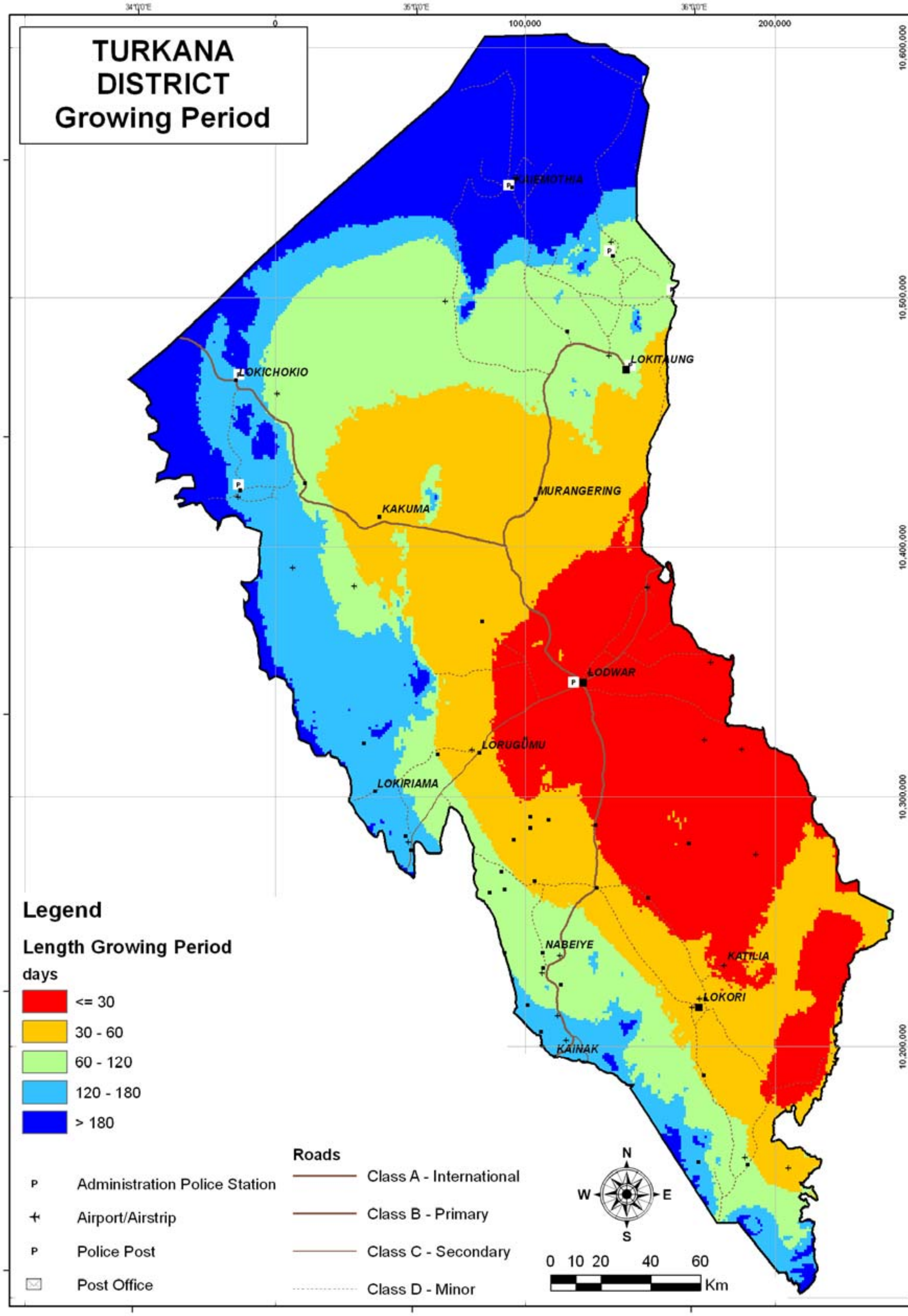
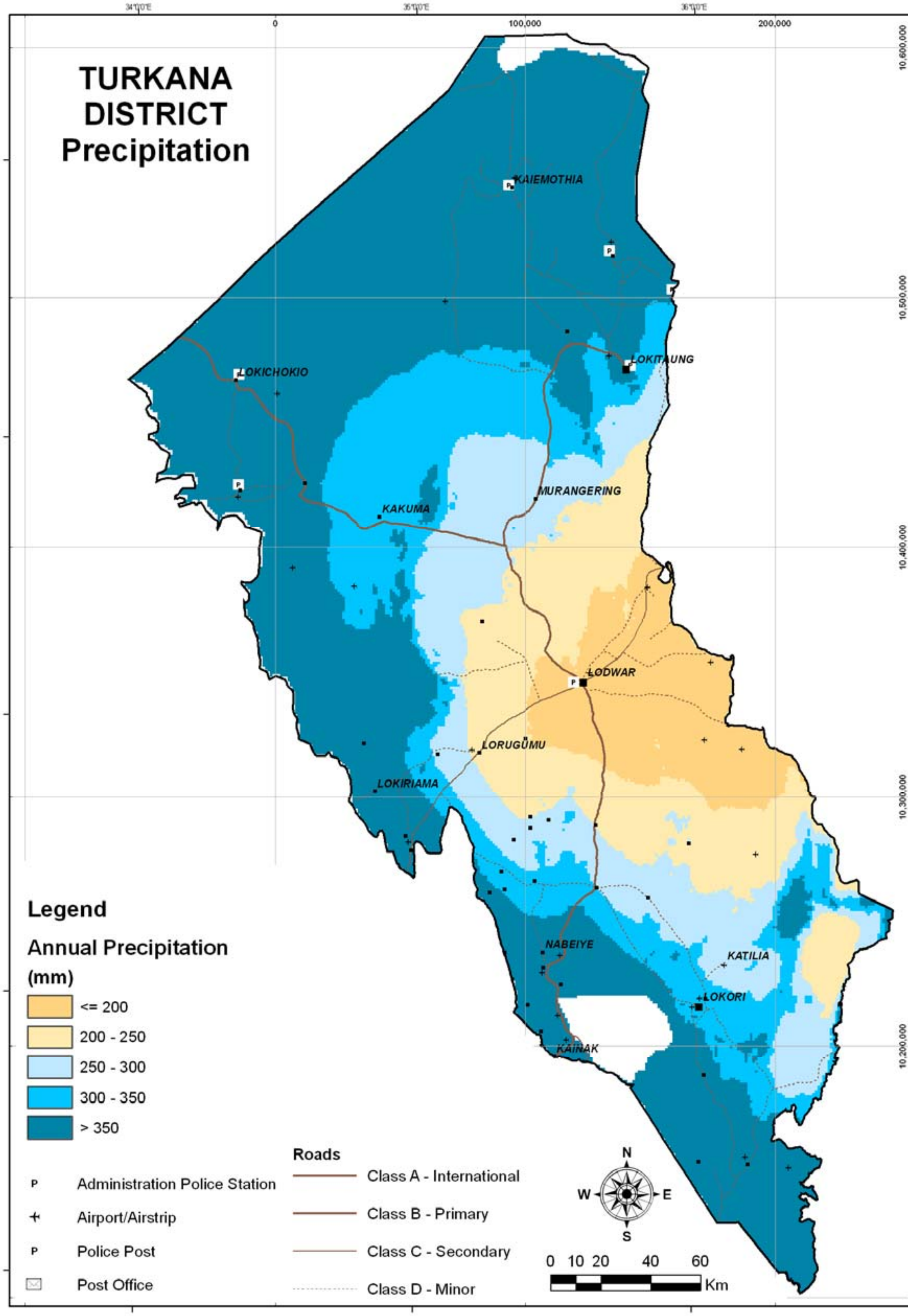
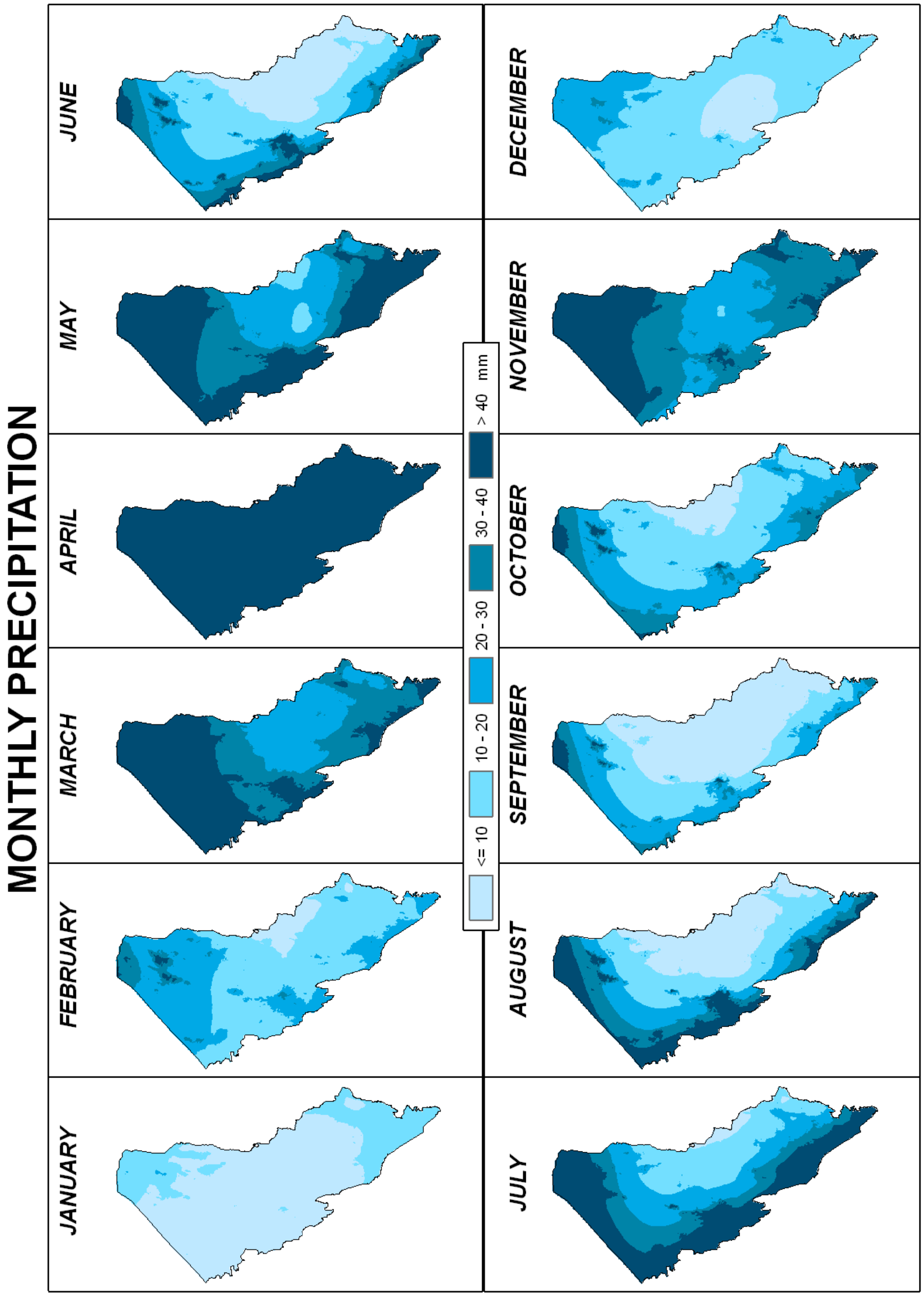


Annex 2: Source Data for Modelling

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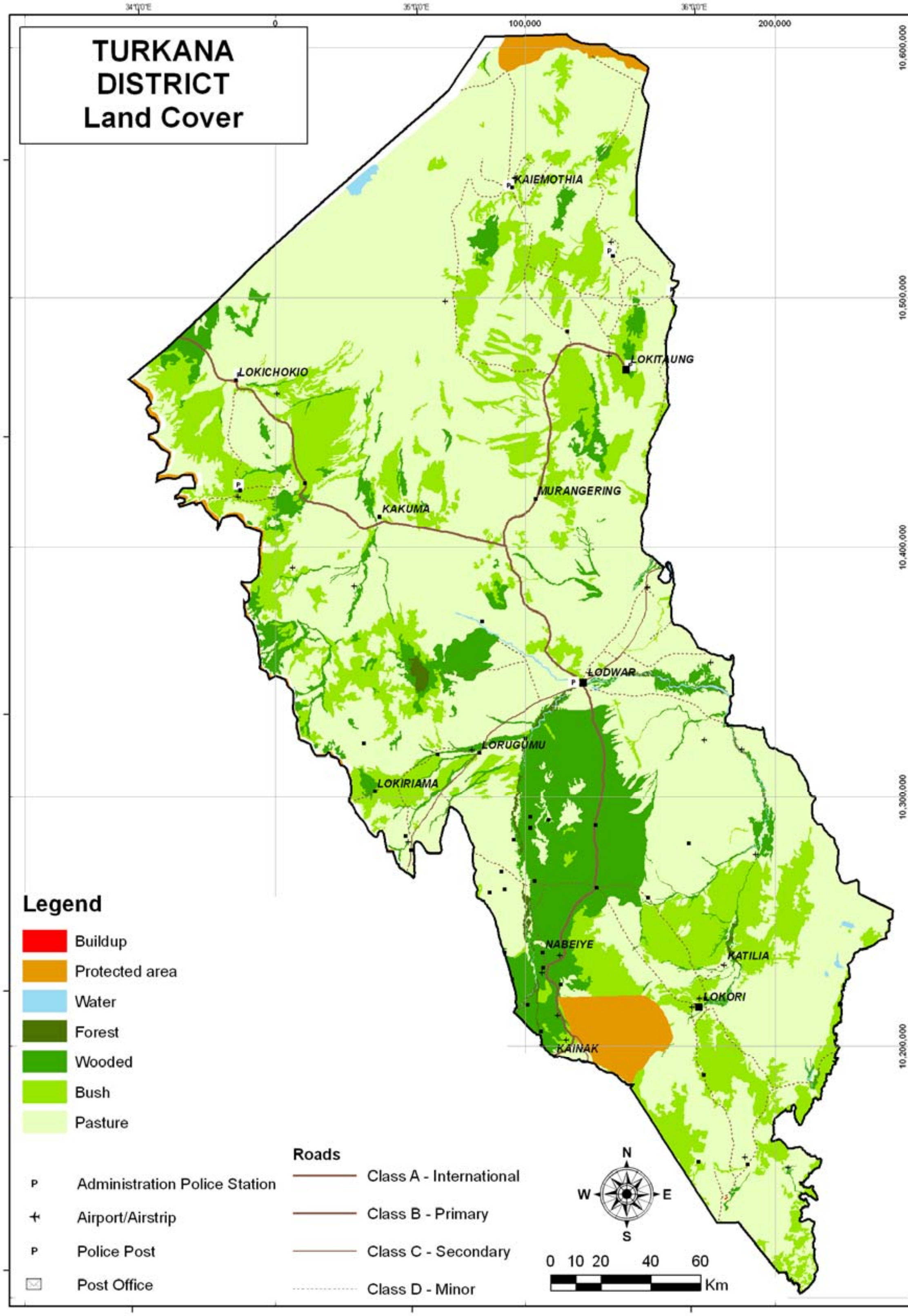
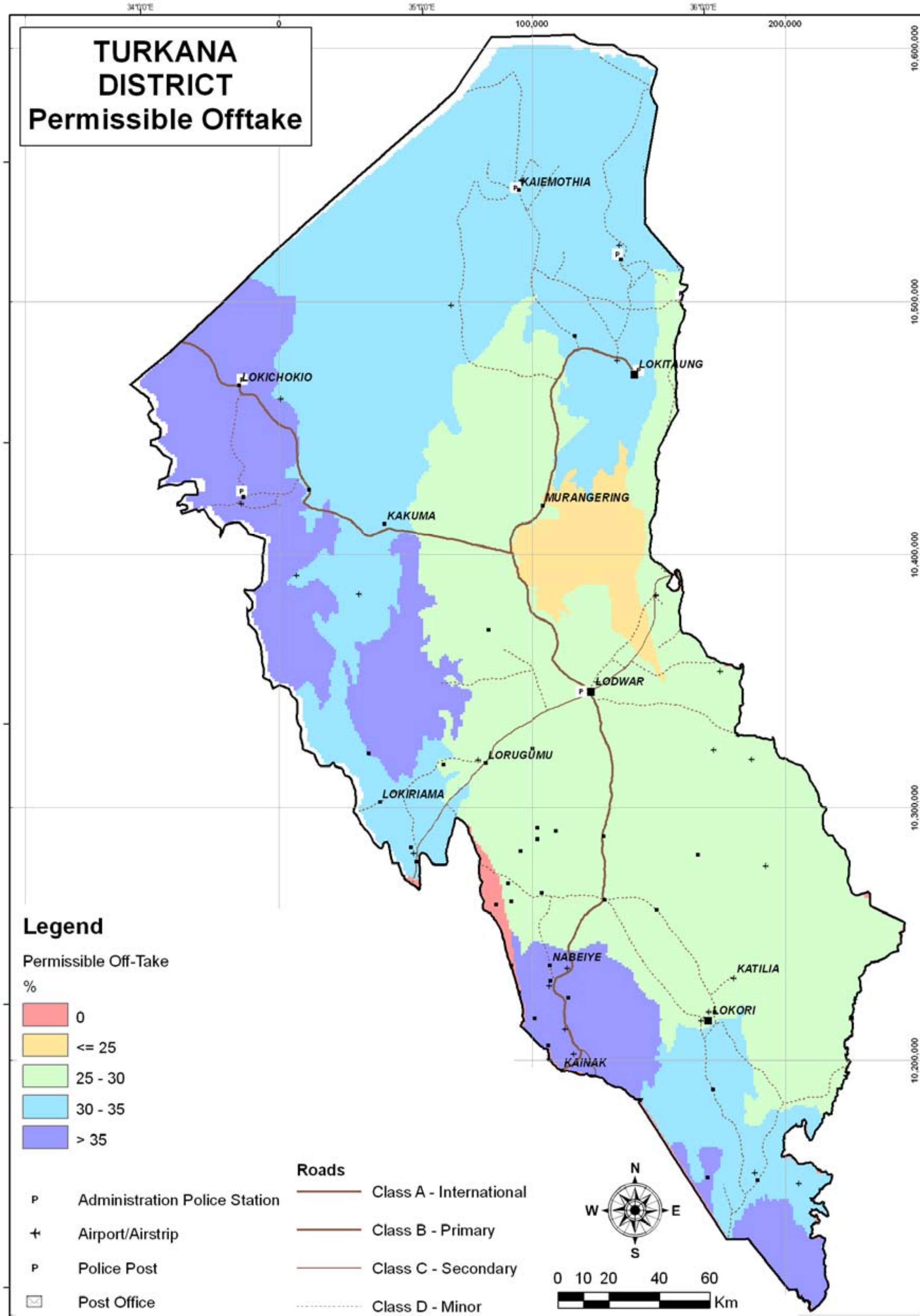
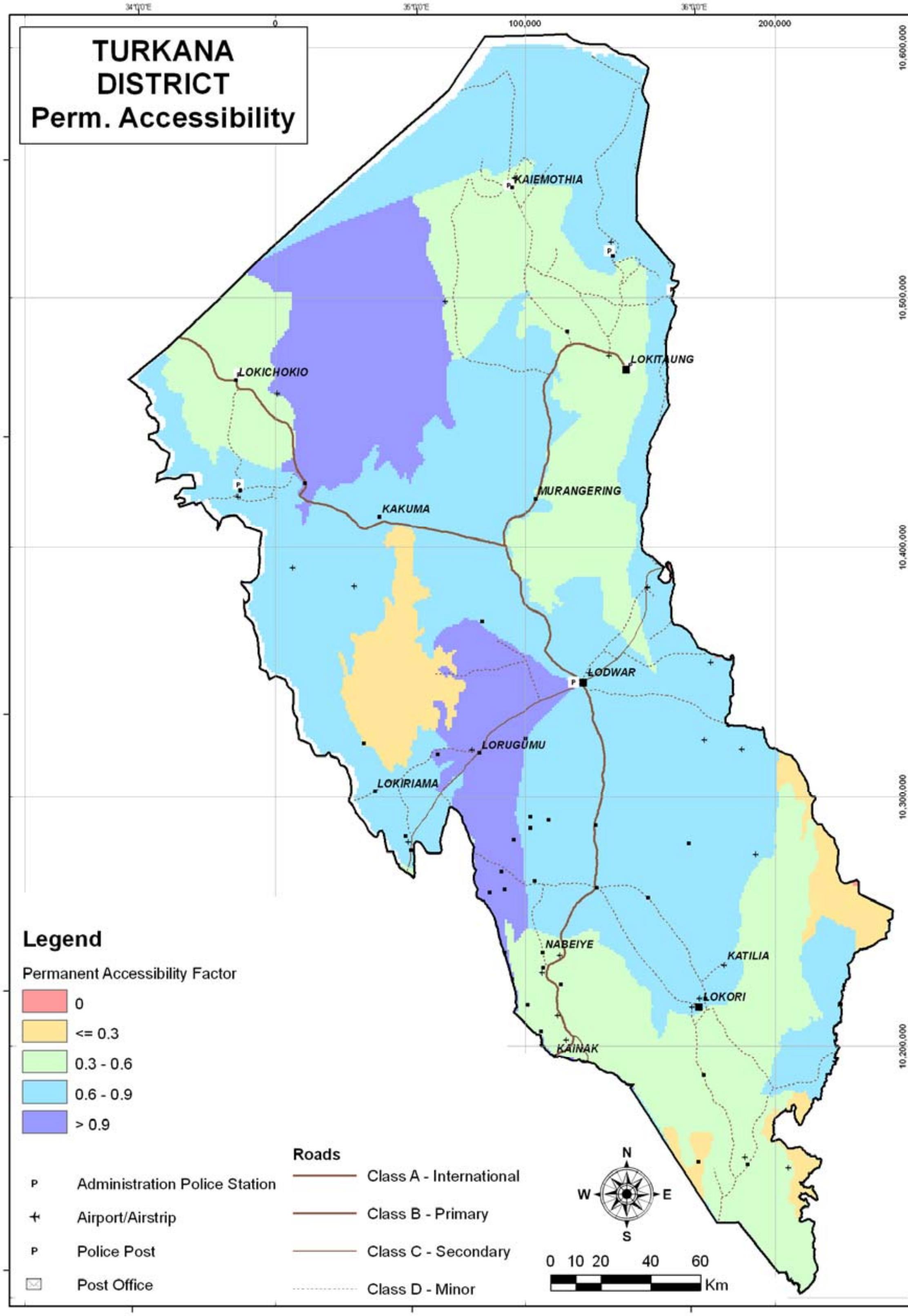
30 - 40
> 40 mm

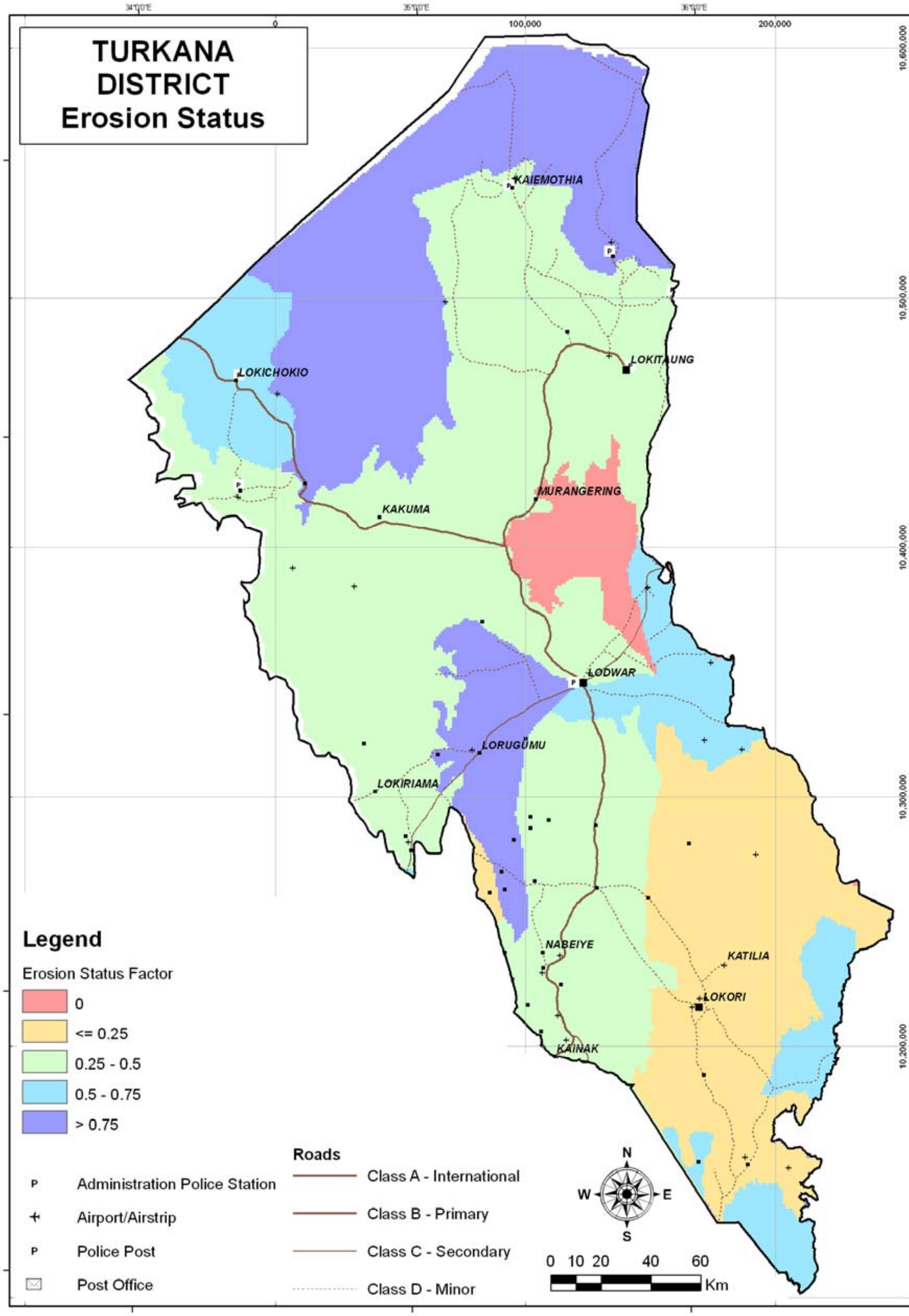

TURKANA
DISTRICT
Land Cover
KAIEMOTHIA
LOKITAUNG
LOKICHOKIO
MURANGERING
KAKUMA
LODWAR
LORUGUMU
LOKIRIAMA
NABEIYE
KATILIA
LOKORI
KAINAK
0
100,000
200,000
10,600,000
10,500,000
10,400,000
10,300,000
10,200,000
Legend
Buildup
Protected area
Water
Forest
Wooded
Bush
Pasture
Administration Police Station
Airport/Airstrip
Police Post
Post Office
Roads
Class A - International
Class B - Primary
Class C - Secondary
Class D - Minor
N
W
E
S
0 10 20 40 60
Km



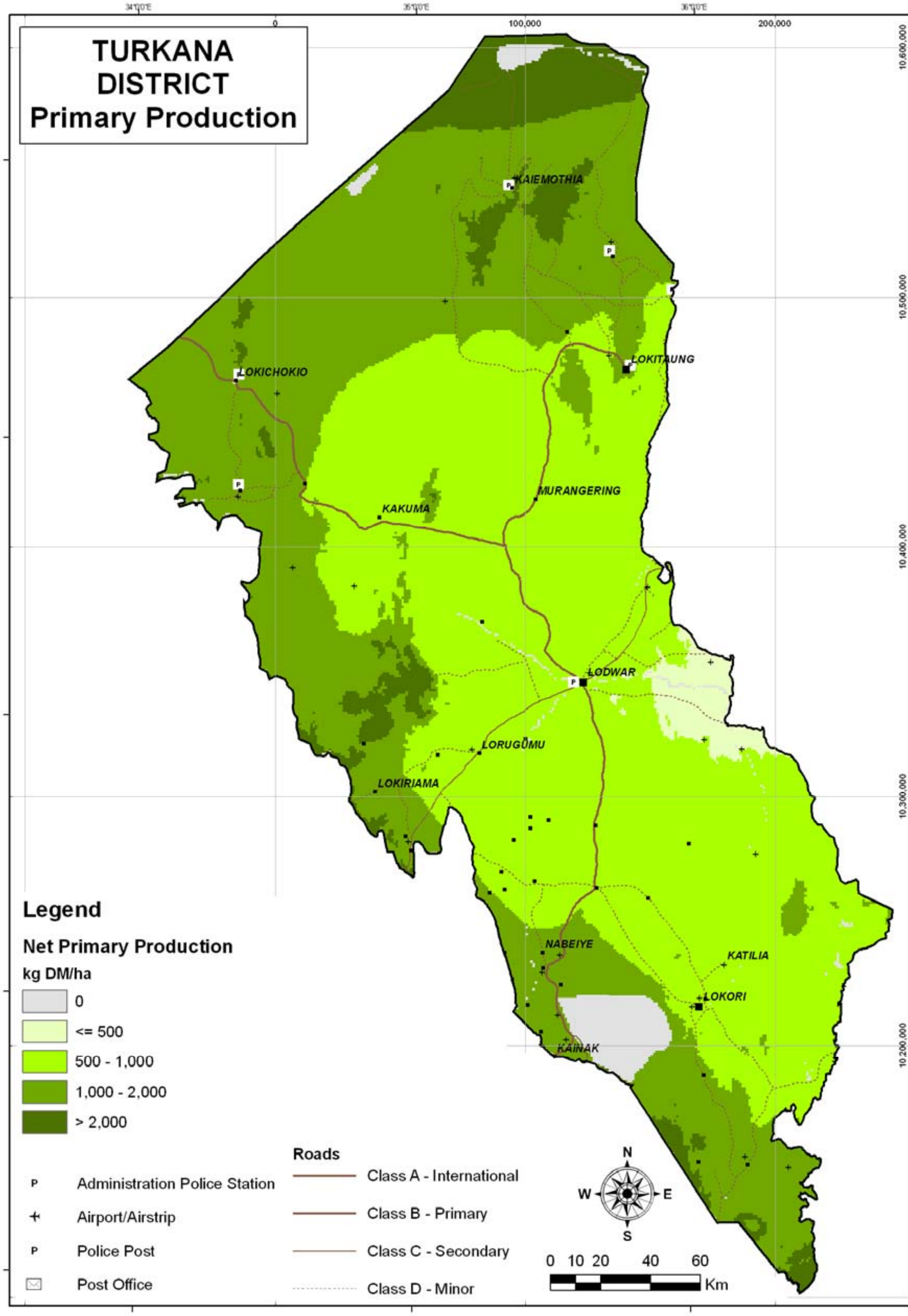
TURKANA
DISTRICT
Permissible Offtake
0
100,000
200,000
10,600,000
10,500,000
10,400,000
10,300,000
10,200,000
KAIEMOTHIA
LOKICHOKIO
LOKITAUNG
MURANGERING
KAKUMA
LODWAR
LORUGUMU
LOKIRIAMA
NABEIYE
KATILIA
LOKORI
KAINAK
Legend
Permissible Off-Take
%
0
<= 25
25 - 30
30 - 35
> 35
P Administration Police Station
Airport/Airstrip
P Police Post
Post Office
Roads
Class A - International
Class B - Primary
Class C - Secondary
Class D - Minor
N
W
E
S
0 10 20 40 60
Km

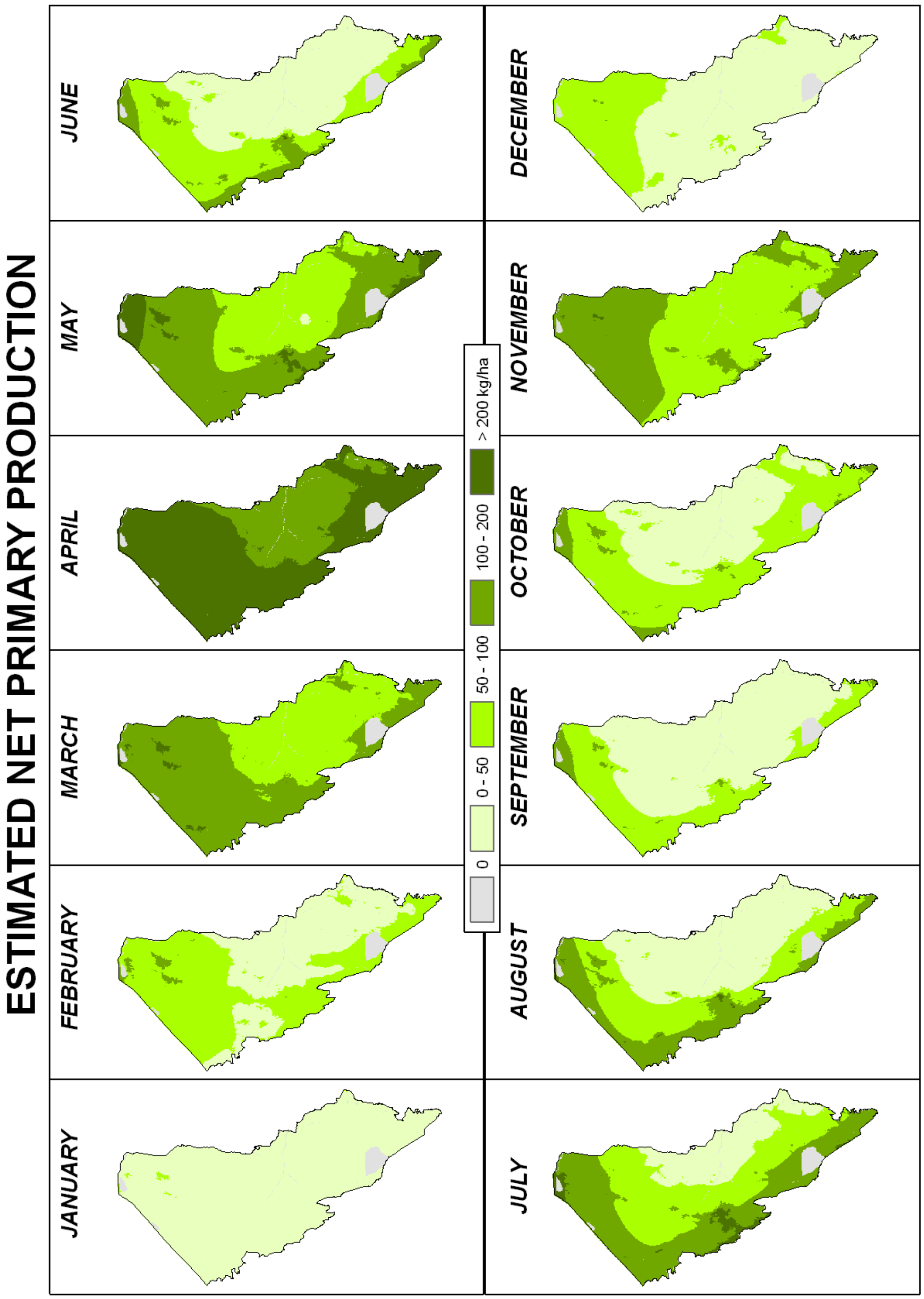


TURKANA
DISTRICT
Perm. Accessibility
KAIEMOTHIA
LOKITAUNG
LOKICHOKIO
MURANGERING
KAKUMA
LODWAR
LORUGUMU
LOKIRIAMA
NABEIYE
KATILIA
LOKORI
KAINAK
100,000
200,000
10,600,000
10,500,000
10,400,000
10,300,000
10,200,000
Legend
Permanent Accessibility Factor
0
<= 0.3
0.3 - 0.6
0.6 - 0.9
> 0.9
Roads
Class A - International
Class B - Primary
Class C - Secondary
Class D - Minor
Administration Police Station
Airport/Airstrip
Police Post
Post Office
N
W
E
S
0 10 20 40 60
Km

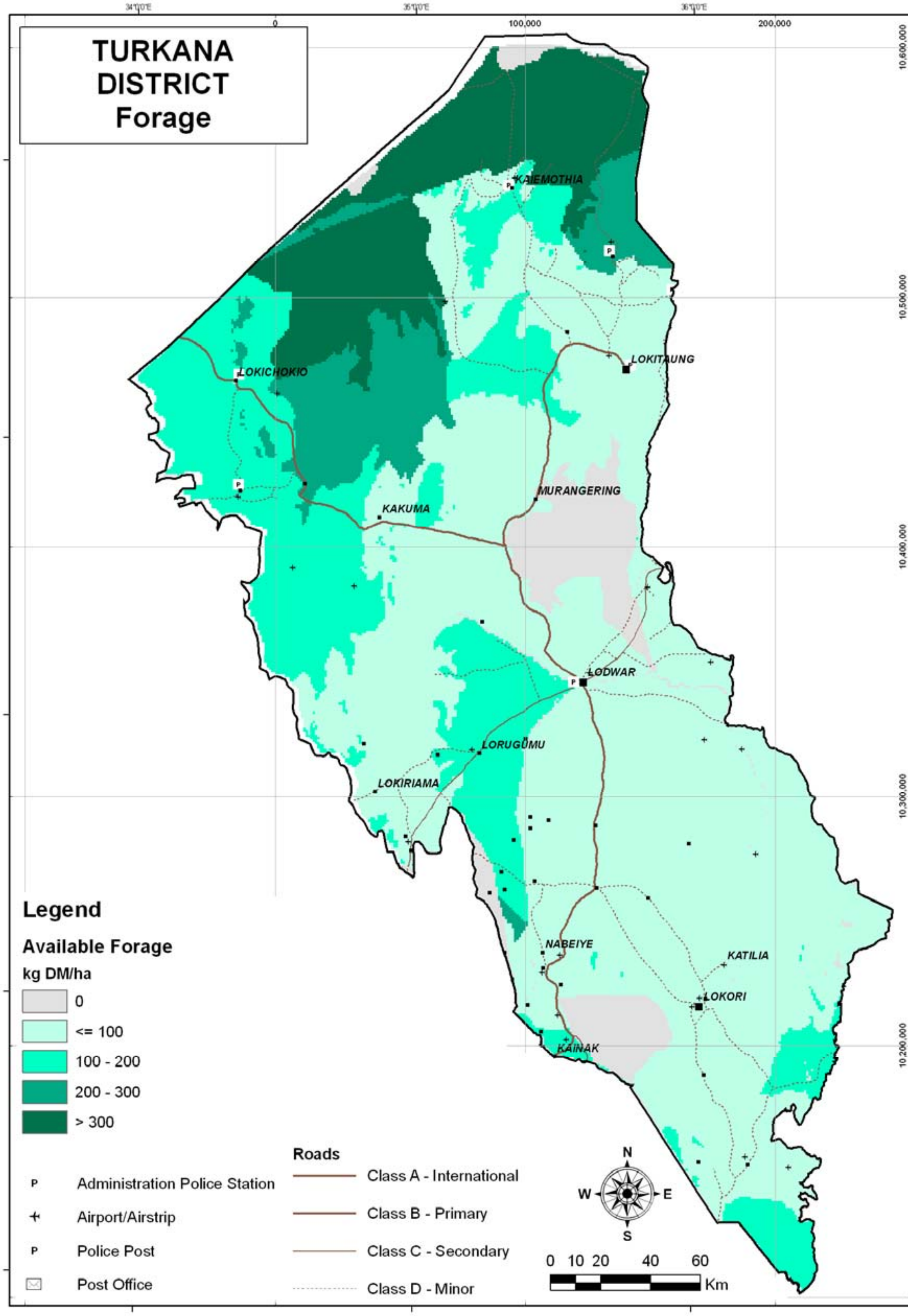

TURKANA
DISTRICT
Erosion Status
KAIEMOTHIA
LOKITAUNG
LOKICHOKIO
MURANGERING
KAKUMA
LODWAR
LORUGUMU
LOKIRIAMA
NABEIYE
KATILIA
LOKORI
KAINAK
100,000
200,000
10,600,000
10,500,000
10,400,000
10,300,000
10,200,000
Legend
Erosion Status Factor
0
<= 0.25
0.25 - 0.5
0.5 - 0.75
> 0.75
Roads
Administration Police Station
Airport/Airstrip
Police Post
Post Office
Class A - International
Class B - Primary
Class C - Secondary
Class D - Minor
N
W
E
S
0 10 20 40 60
Km

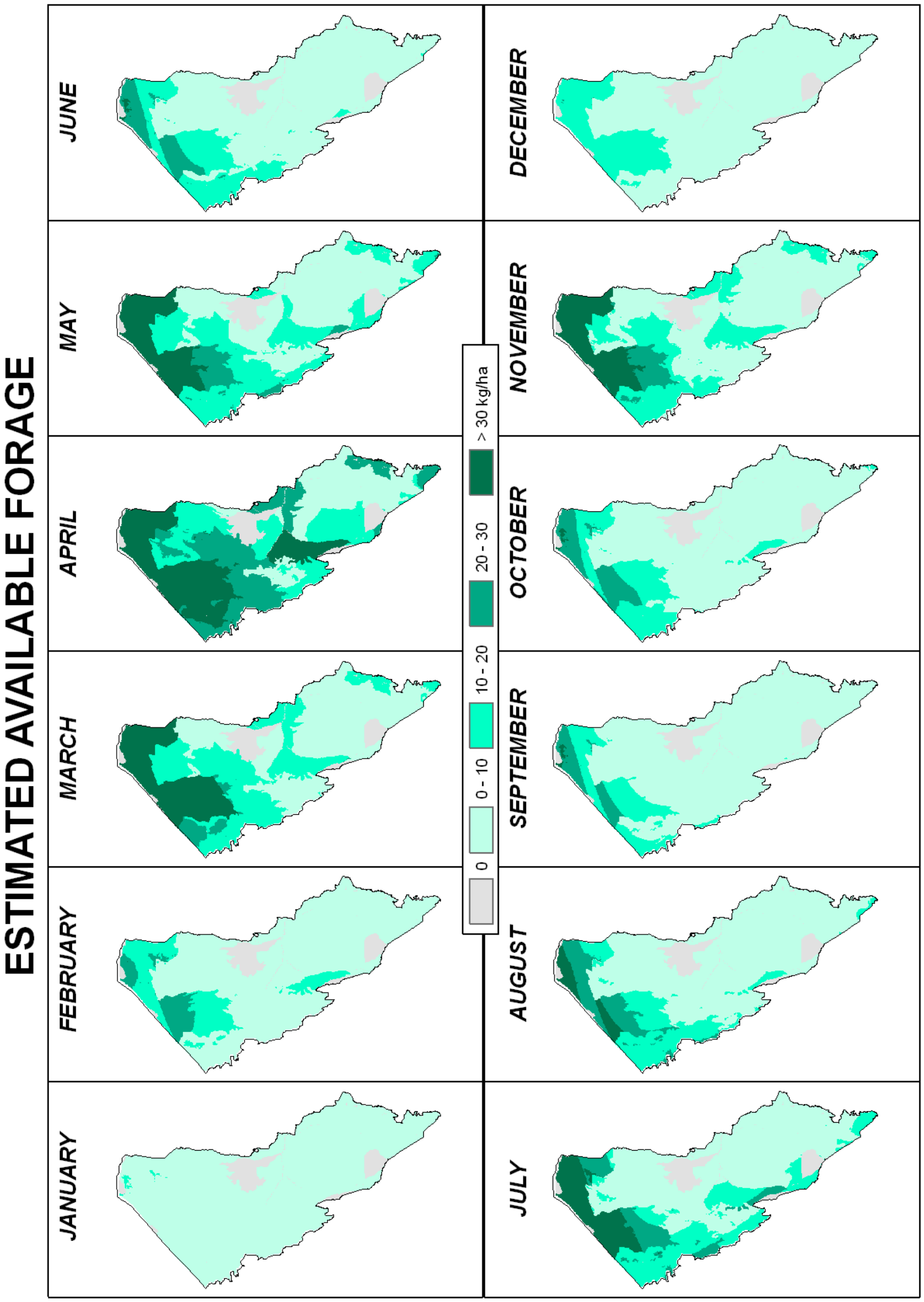
Annex 3: Feed Balance modelling – maps



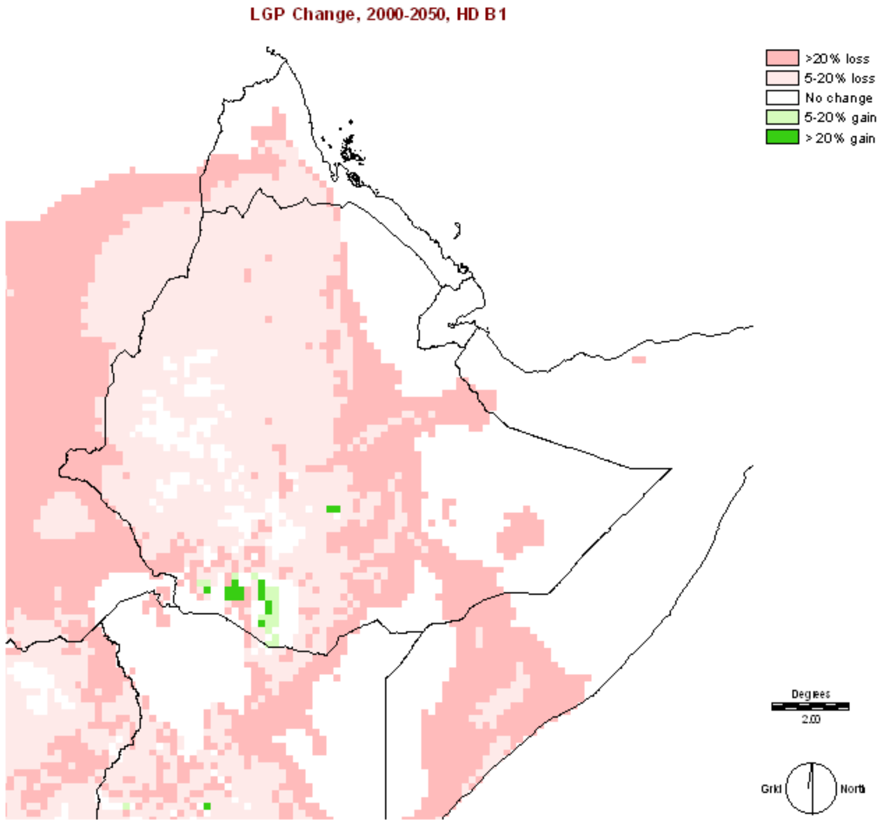

ESTIMATED NET PRIMARY PRODUCTION
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
0
0 - 50
50 - 100
100 - 200
> 200 kg/ha

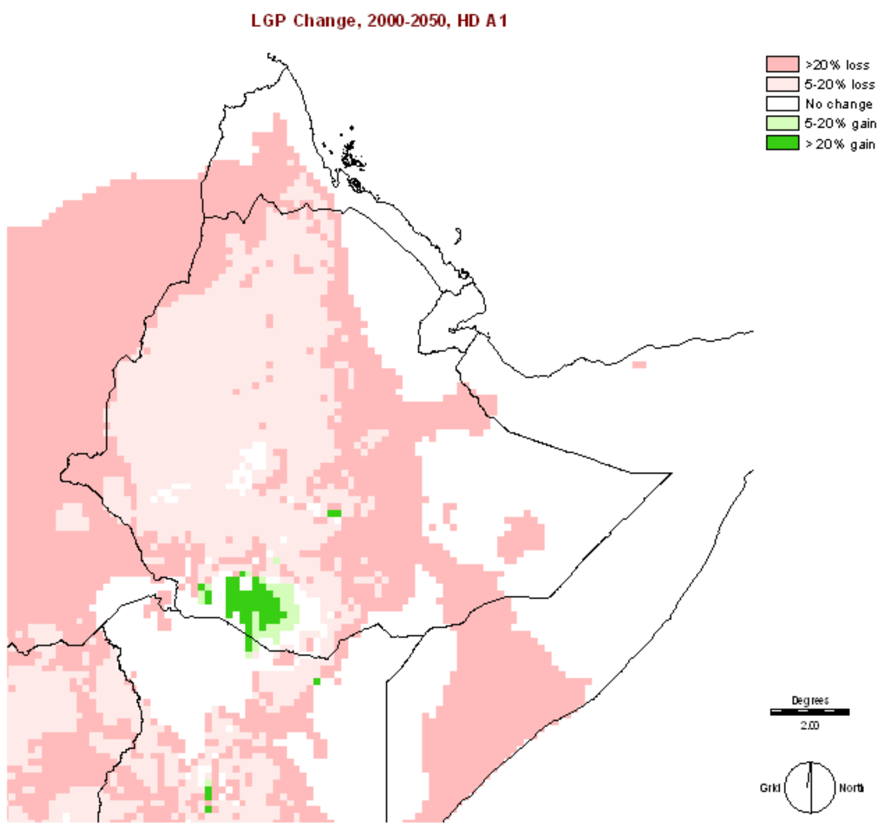
Annex 3: Feed Balance modelling – maps

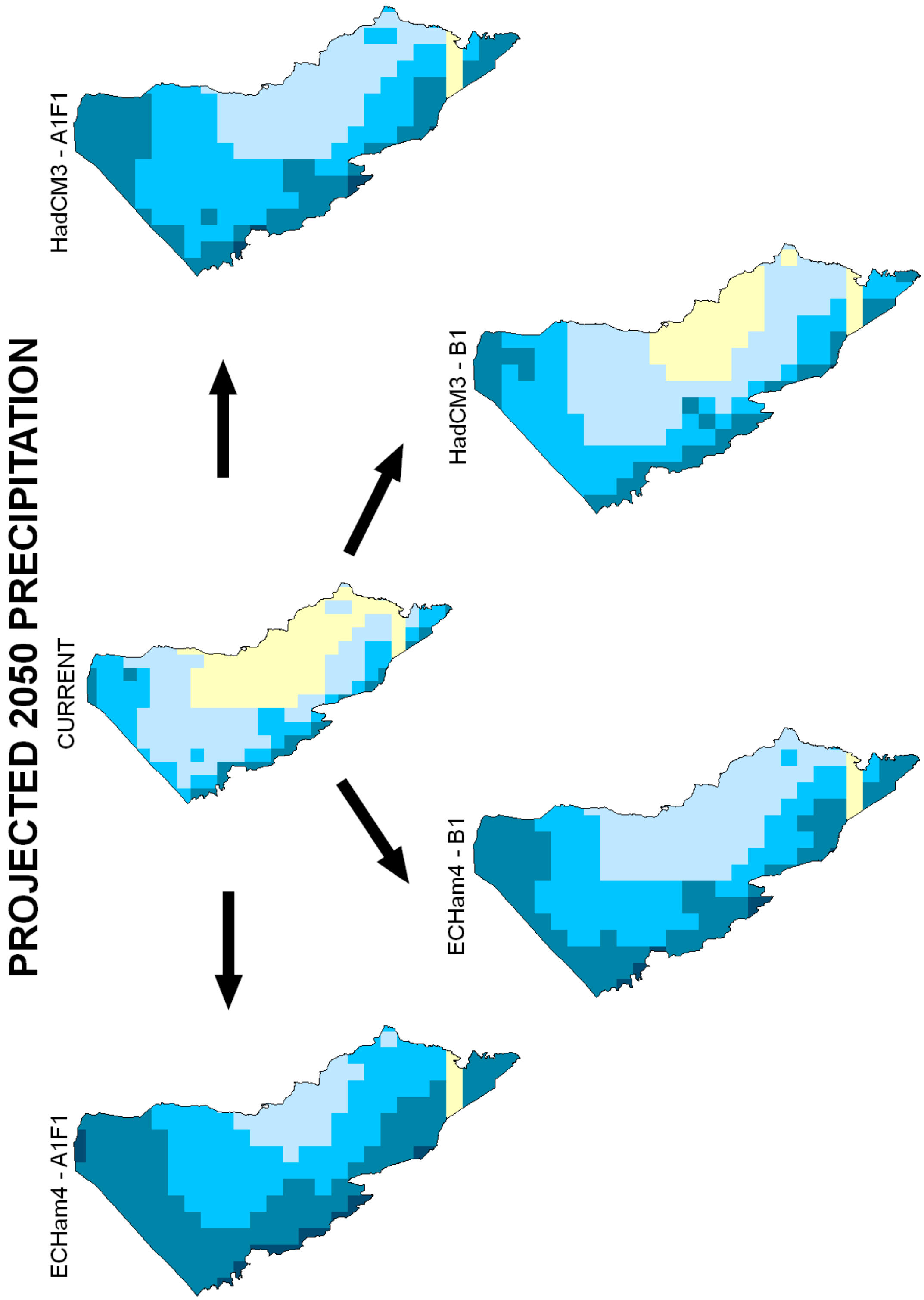


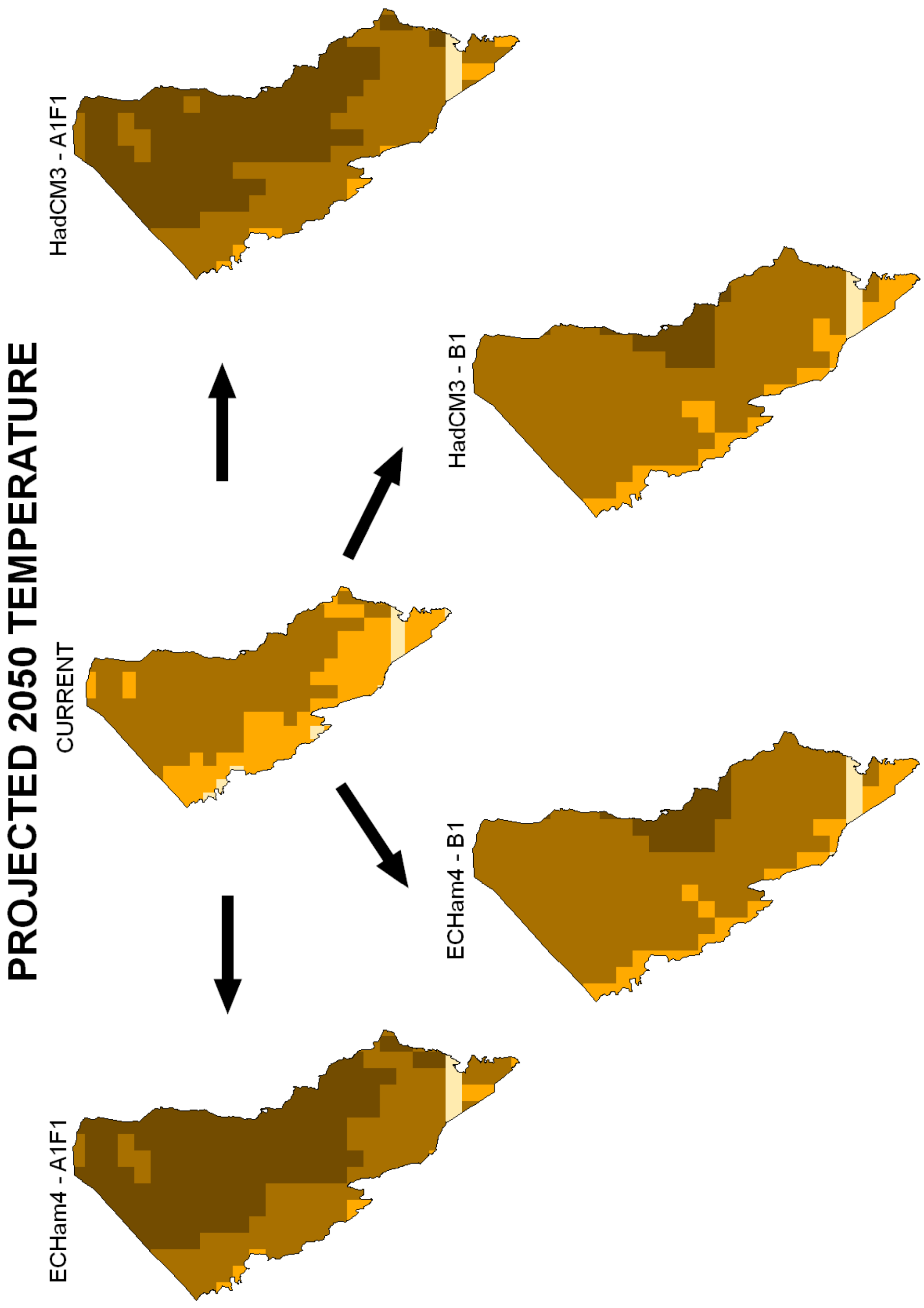

ESTIMATED AVAILABLE FORAGE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
0
0 - 10
10 - 20
20 - 30
> 30 kg/ha

Annex 4: Climate Change modelling - maps






PROJECTED 2050 PRECIPITATION
HadCM3 - A1F1
CURRENT
HadCM3 - B1
ECHam4 - B1
ECHam4 - A1F1


PROJECTED 2050 TEMPERATURE
CURRENT
HadCM3 - A1F1
HadCM3 - B1
ECHam4 - B1
ECHam4 - A1F1

The challenges of contemporary pastoralism in Turkana

Whilst pastoralism, as the principal livelihood, has existed in Turkana for 9,000 years (Blench, 2000), a series of rapid and external developments in the 20th and 21st Centuries have tended to severely compromise long-distance opportunistic movements of livestock (Blench, 2000). One such development has been the establishment of national frontiers; the relatively uncontested migration between what are now Uganda, Sudan and Ethiopia no-longer exists. The establishment of national frontiers has been further compounded by a spate of severe droughts throughout the past 40 years. These droughts have placed significant pressure on the livelihoods of nomadic pastoralists in Turkana; causing catastrophic losses of livestock (capital and savings). Drought was identified as the principal constraint to livestock-based livelihoods in Turkana by the majority of livestock producer and livestock traders interviewed as part of this study.

Furthermore, the impact of drought is particularly acute for poorer members of communities with smaller livestock holdings and less developed social support networks. The consequence is that droughts, combined with restricted migration options, now cause significant humanitarian problems and localised degradation of natural resources, since large numbers of animals converge on certain pastures, especially around wells. This in turn is responsible for long-term impoverishment among pastoralists, since they must sell animals cheaply and cannot afford to re-buy them when the drought ends. At the same time, it places extra stress on already ineffectual veterinary services, since weakened animals are more susceptible to pathogens (Blench, 2000).

Spatial marginalisation of pastoralists is another major present day concern. Pastoralists are continually being pushed further and further into increasingly inhospitable terrain, with greater risks of climatic uncertainty, as technical advances allow agriculture and agro-pastoralism to spread into new areas traditionally utilised by nomadic pastoralists (Blench, 2000).

Increasing human and livestock populations (see below for a full discussion) also add to the risky nature of nomadic pastoralism in Turkana by increasing pressure on progressively scarce and fragile natural resources (Berger, 2003). This was exacerbated in the 1980s years by the introduction of trypano-tolerant breeds, trypanocides, enhanced veterinary care and the elimination of tsetse habitat (Blench 1995). Because pastoralism is geared to the reproduction of the herd there is inevitably a surplus of animals, such as most males and those females whose reproductive span is over, which can be disposed of without affecting the reproductive capacity of the herd (Hogg, 2003). One of the inevitable consequences of this is that, without intervening factors, livestock populations will eventually exceed the capacity of the range to support them Hogg, 2003).

Ultimately, political constraints to livestock migration, an increased lack of pasture and water due to severe droughts and encroachment onto traditional dry season pasture by agro-pastoralism, and growing human and livestock populations has led to increased competition and less co-operation between tribal clans within Turkana, and, between neighbouring tribes, in Pokot (Kenya), Uganda, Sudan and Ethiopia. When livelihood strategies fail, conflict and livestock raiding becomes common place and violence extends from rural to urban areas (Berger, 2003). After drought and livestock diseases, insecurity was mentioned as the third most important constraint to pastoralists' livelihoods; it was particularly emphasised around Lokichar, Turkana.

Climatic shocks in the past two decades have pushed an increasing number of pastoralists deeper into abject poverty, prompting huge flows of international humanitarian aid into the ASAL (McPeak and Barrett, 2001). With the exception of one or two notable interventions, national governments, international agencies and NGOs have traditionally responded to the problems faced by pastoralists in Turkana by putting into place food relief mechanisms. According to Blench (2000), these interventions resulted in maintaining unsustainable levels of human and livestock populations in the District. Blench (2000) insists that there is considerable historical evidence that pastoralists who could not succeed in difficult climatic conditions, or who lost their herds through disease, would simply leave the agro-ecological zone and become settled farmers or traders. This is a brutal but effective mechanism of reducing pressure on resources. However, the provision of food aid has the effect of keeping in place populations who would otherwise move and initiate a new subsistence strategy (Blench, 2000).