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Postgraduate course

Land Dynamics

Getting to the bottom of Mount Kenya

Studying land-use dynamics and sustainable development in an interdisciplinary setting

Kenya, 26 April - 9 May 2015

Reader

The C.T. De Wit Graduate School PE&RC PRODUCTION ECOLOGY & RESOURCE CONSERVATION

SENSE Research School for Socio-Economic and Natural Sciences of the Environment

Wageningen School of Social Sciences

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A. Course Overview

1. Scope

The dynamics of land systems (past, present, future), as well as the vulnerability to change, are determined by a set of biophysical, socio-economic and governance drivers. The manner in which these drivers affect the components of the system accordingly determine the appearance of the landscape and its potential use. To comprehend these complex dynamics a multi/interdisciplinary approach is required where the system and all the driving components are regarded as a whole.

This course addresses the interdisciplinary and multi-scale analysis of the dynamics of land systems, covering the geological, ecological, land use, societal and governance perspectives over different scales of time and space. The ***main goal*** of the course is to investigate past and current dynamics of the region and predict possible futures.

2. Focus and Learning goals

The course aims at the study of complex land systems. The course specifically focuses on the spatial variability, the multi-faceted nature, and the dynamics of these systems. The analysis requires input from multiple disciplines where the underlying processes have an inter- or trans-disciplinary character.

Specifically, after the course participants can
- describe the variability of complex farming systems and landscapes,
- conceptualize the farming system in a broader land system, i.e., develop a conceptualize model,
- derive key processes underlying the dynamics of landscapes through a combination of legacy data, field work, and stakeholder interviews,
- have insight in the variation in techniques for landscape analyses applied in various disciplines,
- define and analyse alternative scenarios through different techniques, and
- interpret and combine legacy data and recognize its strengths and weaknesses

3. Set-up

The course is held in the Embu region of Kenya and involves a combination of lectures, discussions, debates and a significant amount of field work which revolve around a set of consecutive topics and assignments (see below).

<u>Lectures</u>
Lectures will be on an overview of, or in-depth insight in, relevant aspects of the Embu region and/or topical elements in the field of land dynamics.

<u>Debates</u>
Debates will be on specific topics which are highlighted in the course. The session starts with 10-minute introductions by course lecturers addressing the topic from their perspective. After a short round of questions the floor is open for a 30 minute debate on the topic addressed.

<u>Group work</u>
Participants will be split into 4 groups where each group will focus on an area in the Embu region with a specific land-use system. During the course groups must collect, analyse and synthesise information to come with a view of past and current dynamics of the system under investigation, the main drivers and a prediction of possible futures.
Each group has the task to do this analysis for one of the three locations identified:

1. Upper highlands - The transition zone between the natural systems of Mount Kenya National park and the upper tea zone
2. Highlands – The tea zone
3. Lower highlands – The mixed farming (dairy, coffee, maize, fruit and vegetables)
4. Lowlands – Pastoral systems and extensive agriculture

Collection of data will occur via:

- Literature/documentation research: A significant source of information will be available but more can be sought for via internet and local sources
- Fieldwork: The groups will visit their area and gather data through interviews and field observations. An array of factors can be included in determining the land dynamics, such as: soil fertility, erosion, water (availability, flow, distribution and quality), food security (quality and quantity), livelihood, income, labour, migration, etc.

After field work, groups will analyse and discuss what they have found. Regularly groups will briefly present their findings, where they stand, the way forward and what the possible issues might be. The rest of the attendees will accordingly reflect and give input.

Modelling (both conceptual and dynamic) will be a central element of the course that supports groups in synthesising and coming to understanding of the drivers and states of the systems' dynamics.

The course will end with a presentation session in which each group present their final result of the past and current dynamics of the region and their prediction of possible futures.

4. Study area

The Embu district on the slopes of Mount Kenya is the study site of the course as it is a highly dynamic region with rapid changes in socioeconomic, biophysical, governance and consequently land use. Moreover, the region is subjected to conservation activities, poverty and seemingly unsustainable land uses.

The Eastern side of Mount Kenya is divided into two regions, the Embu and Mbeere district. The total area spans an altitudinal and land use gradient from the semi-arid savannah, to farms of tea, coffee and maize, to bamboo and tropical montane forests and glaciers at the peak. The elevation along this gradient ranges from 760 m to 2070 m with precipitation varying between 640 mm/yr to 2000 mm/yr. Soils also vary along this gradient. In general, they are deep and well drained, except for imperfectly drained valley bottoms and soil fertility decreases from the high areas to the low areas.

Population densities range from 20 people/km^2 in the lower zones to over 700 people/km^2 in the higher zones. The diversity of ecosystems and landscapes, combined with rapid economic and social change, has led to land use and cover change that vividly reflects evolving social and environmental patterns and processes.

Under pressure of the government, the land system changed from small areas of shifting cultivation to permanent private family farms. This had many consequences, including a widening gap between rich and poor, insufficient farm sizes, loss of soil fertility, increase in use of manure and pesticides, migration of husbands and sons, and off-farm activities.

To date, the economy of the Embu district Embu is brittle and poverty is a major problem. Together with droughts, unreliable rainfall and population growth, this area is facing more changes in the future.

5. Topics and assignments

In the course 5 consecutive topics will be dealt with, each having specific objectives and assignments. The assignments are meant to help with structuring the course, so the groups can gradually work towards the main goal. Hence, the assignments are tools and not goals itself. Assignments are generally split into sub-assignments, of which the outcomes will be discussed and evaluated. All documents written and work done must be collected and stored by the groups themselves.

Together you will reflect on the outcome, the level of interdisciplinarity and how it has contributed in taking the overarching group assignment forward. Below you can find the topics and the assignments:

1: Embu: The birds-eye view

Study of available information on the Embu district on a certain topic. Each group get a specific factor of land dynamics prominent in the Embu region that they must gather information on and compile into a 15-minute presentation which will be followed by 5 minutes discussion. Each group gets one of the following topics:

1. Abiotic factors (e.g. soil, water, topography)
2. Biotic factors (e.g. natural vegetation, crops, animals, ecology)
3. Social factors (e.g. villages, homesteads, institutions)
4. Economic factors (e.g. markets resources available such as taps, housing, transport, material status)

2: Variability: Spatial, temporal and between disciplines

Large discrepancies can often be seen between data and reality in the field. These discrepancies can be due to variance in spatial and temporal scale of data and actual observations as well as differences in theory, methodology and interpretation between disciplines. This variability is the focus of the first topic. In the process you will get insight in the present situation in the Embu region and a first impression how land use is organised. Insight and data obtained will contribute to the first version of a conceptual model of land dynamics that the groups must develop.

2.1: Virtual Walk

Each group performs a virtual walk through their assigned area/system, using information obtained from the various available data sources. Information is obtained from the reader, literature and documentation available in a Dropbox folder, the internet and possibly information from local sources.

The following must be taken into consideration:

- Abiotic factors (e.g. soil, water, topography)
- Biotic factors (e.g. natural vegetation, crops, animals)
- Social factors (e.g. villages, homesteads)
- Economic factors (e.g. markets resources available such as taps, housing, transport, material status)

Each group joint tackles these factors dividing the tasks amongst themselves describing the drivers and states. Accordingly the group compiles the information in one (short) joint document describing what one would expect to see when walking through the area. This is transferred to a power point as the first step of the presentation after the next day’s field visit (2.2).

2.2: Field Visit

Each group visits their area and walks a transect describing the system as it actually is, considering the factors mentioned in 2.1. Accordingly they compare the outcome of the virtual walk with reality and identify possible causes for the differences in descriptions from field and databases. Groups also focus on new elements that have not yet been considered regarding land dynamics of their study area.

Accordingly groups convene for lunch after which we all visit the individual areas where each group presents their findings regarding virtual walk and observed reality.

The assignment is wrapped up in the evening where key learning points of the day are discussed

3: In search for the historical perspective: From past to present

In the first stage you have developed a first insight in the area. Building upon this quick-scan, including the first conceptual model and ideas about drivers and dynamics, you are now going to develop an in-depth insight in the systems, their drivers and dynamics over time. Starting from the current situation, the first question is how did this situation emerge? As such, the overall objective of this stage is to understand most important drivers in land use change, their internal dynamics and interrelated dynamics over time. Hence, groups must investigate what their area looked like in the past (e.g. 5, 10, 20, 30 years ago or even earlier) and what drivers made it to what it is today.

3.1: Develop a conceptual model of the current situation

Based on the information obtained so far (lectures, discussion, assignment 1 and 2) determine the drivers and dynamics of system dynamics in your area and translate this into a first conceptual model.

3.2: Identify processes and drivers of change

Go through the databases and literature focussing on the vital processes and drivers and reconstruct these over time. Note to consider local, regional, national as well as international drivers of change. Based on this analysis, develop a sampling scheme or set of selection criteria and select three sites to study the various processes identified in the former assignment. All with a different historical development. In addition, identify the gaps, and remaining questions that need to be addressed in developing your conceptual model further.

3.3: Plan of action for next day’s field work

Based on outcome of 3.1 and 3.2 identify what data need to be collected to obtain a complete insight in the drivers and processes that influence the dynamics. Identify which (field) methods can be used. What are the pro’s and con’s? To which processes can the methods be applied? Then select the methods you will use in the field the following day and make a plan of action.

At the end of the day each group shares with lecturers where they stand with respect to their model and the plan of action for the next day.

3.4: Field work

Each group travels to their site to spend the day doing field work to validate and check the first version of the model. They are accompanied by two lecturers. Focus on what you see yourself and how locals see it from their perspective as land-user (search for various perspectives on the same processes, drivers and dynamics).

3.5: Interpretation and analysis

Collected data are interpreted, analysed and related to written information. Here too reflect on variability and discrepancies of observations with what the literature, documentation tells us. Where do they come from? What is the meaning of these differences and how do they influence your model? Apart from qualification divers and processes must also be quantified. The model is adjusted accordingly and the group records what data are still required to get the complete picture of the system dynamics in their area.

Presentation: Present the historical perspective on land use dynamics on Mount Kenya (for your specific sites in relation to the region), and the implications for your model (15 minute presentation and 10 minutes discussion).

4: Modelling complex systems

In the third assignment you have developed a historical perspective on vital processes in land use dynamics. The outcomes of this complex exercise give valuable information for your model. In this stage you are going to develop your model further from a conceptual into a simple simulation model. The objective for this stage is therefore to develop and fine-tune a simulation model for land dynamics of your area.

4.1: Develop a simulation model.

During the course several models are introduced. Which of these model helps to further elaborate the conceptual model into a simple simulation model? Do you need parts of several models? Combine, adjust and modify the model(s) in such a way that it is a specification of the conceptual model.

4.2: Remaining gaps

Identify the remaining gaps and information needed to fine-tune the model. Pay special attention to the part you are not certain about. Because it is one of the last possibilities to go into the field we advise you to prepare it well. Go into the field to gather information that 1. helps you to fill the gaps identified, and 2. verify the model and take away (part of the) uncertainties identified.

4.3: Fine-tune and reflect

With the information of the foregoing days you can now fine-tune the model. After fine-tuning the model reflect on the strong points of the model. What does it show? What does it “hide”? What can be improved? Discuss not only the output of the model, but be also critical and transparent on the input and way the data is processed.

Presentation: present the final model including critical reflection in no more than 15 minutes. Based on your work on the model and findings we expect you to present several points for the discussion. Based on the presentation we will discuss interactions between the case study areas. You are expected to write draft conclusions on the own model and cross case relations.

5: Scenario analyses

In land use policy, scenario development is one of the most important policy instruments. Different types of scenarios exist each used for various reasons (e.g. discussions, development perspectives, impact analysis, explore robustness of strategies). In this stage you are going to work on regional policy issues for Embu. Based on your model and policy issues on sustainable development you are going to work on two scenario's that show potential but diverging developments. The objective of this phase is to show and discuss the potential impact of sustainable policies for the Embu region.

5.1: Define policy question

Several (parts of) policy documents will be handed out. In addition, a general policy question will be given. Based on this input you should be able to define a definitive policy question and objective for the scenarios. Work also on the following questions: what do you need to develop diverging scenarios, which elements of presented scenarios are interesting and useful?

5.2: Develop scenarios

Based on the morning sessions and using your model you are requested to develop two scenarios for the Embu region. Develop these two scenarios for the middle to long term (approx. 2030). How will the region possibly look at that time?

Presentation: present the two scenarios in relation to the detailed policy question develop in short presentations (max 10 min.). The presentations will be followed by a short discussion.

6: Finalising

In this short final stage of the course we are looking back and we are looking towards the future. The objective of this stage is therefore twofold: to reflect on the course and to identify windows of opportunity. This stage will end with a discussion (no presentation).

To prepare the discussion the following issues need to be prepared:

- Summarise how you experienced the road from understanding land use dynamics to scenarios and identify the three most important lessons learned and points for improvement.
- Which windows of opportunity do you see considering the data and insights gathered, or in contacts with other PhDs?
- How would you evaluate the research process, which criteria would you use? Applying these criteria what can be said about the secondary data, primary data, analyses and outcome, interdisciplinarity of the process in your group.

  Discussion: group discussion on the points prepared.

6. Course Programme

Date/Time	Activity	Who?
Sunday 26 April	Morning arrival at Nairobi International	
11:30	Travel to Embu Izaak Walton Inn with 4 mini vans	All
14:00	Arrival / unpacking and getting settled	All
15:30	Tea	All
16:00	Introduction to the course including • Course set-up /Programme /Learning objectives • Do's and don'ts (what may and may you not do during field work) • Division in groups • Group Assignments	Lieven / Jetse
17:30	Drinks	All
18:00	Dinner	All
19:00	Poster Carousel: Speed date with posters	Claudius
20:30	End of programme / Free time	All
Monday 27 April	**A disciplinary description of and a virtual walk through the Embu district**	
7:30	Breakfast	All
8:30	Overall introduction to the Embu District	Jetse
9:00	**Assignment 1:** The birds-eye view	Groups
10:00	Coffee break	All
10:30	Assignment 1 continued	Groups
11:30	Assignment 1 presentations	Groups
12:45	Lunch	All
	Assignment 2: Variability: Spatial, temporal and between disciplines	
13:30	**Assignment 2.1:** A virtual walk through Embu description	Groups
15:00	Tea break	All
15:30	Assignment 2.1 continued	Groups
17:30	End of the day / Free time	All
19:00	Dinner	All
20:00	Evening free	All

Date/Time	Activity	Who?
Tuesday 28 April	**Assignment 2.2:** Actual walk through Embu district	
7:30	Breakfast and take packed lunch	All
8:30	Each group visits their research area	Groups
12:30	Lunch in the field with all groups	All
13:30	Visit to individual group sites where each group presents their finding	All
17:30	Back at Izaak Walton Inn / Free time	All
19:00	Dinner	All
20:00	Wrap-up: Key learning points of the day	All
Wednesday 29 April	**Variability: Spatial, temporal and between disciplines**	
7:30	Breakfast	All
8:30	<u>Lecture and discussion:</u> Causes for differences between data and reality (Aggregation, scale, time, generalisation)	Jetse
9:15	<u>Debate:</u> Variability within and between disciplines • Geology/ Geomorphology (Lieven Claessens) • Soil and land use (Jetse Stoorvogel) • Livelihoods (Maja Slingerland) • Landscape planning (Jasper de Vries) • Ecology (Claudius van de Vijver) • Economics and markets (Paul Ingenbleek)	All
10:00	Coffee break	All
10:30	Debate continued	All
12:30	Lunch	All
	Assignment 3: In search for the historical perspective	
13:30	<u>Lecture:</u> How to develop a conceptual model	Lieven
14:00	**Assignment 3.1:** Develop a conceptual model of the current situation	Group
15:00	Coffee	All
15:30	**Assignment 3.2:** Identify processes and drivers of change	Groups
16:30	**Assignment 3.3:** Plan of action for next day's field work	Groups
17:30	<u>Feedback Session with lecturers</u>	Groups
18:00	Drinks	All
19:00	Dinner	All
20:00	Free evening / optional reading and group work	All

Date/Time	Activity	Who?
Thursday 30 April	**Assignment 3.4: Field work (1)**	
7:30	Breakfast, Take-away lunch	All
8:30	Field work	Groups
12:30	Lunch in the field including: • Reflection on morning session together with lecturers • Possible adjustments of plan of action	All
13:30	Field work continued	Groups
17:00	Travel back / Free time	All
19:00	Dinner	All
20:00	Free evening / optional reading and group work	All
Friday 1 May		
7:30	Breakfast	All
8:30	Debate: Understanding dynamics 10 minute lectures followed by a few minutes' questions. At the end there is a debate of 30 minutes • Landscape evolution (Lieven) • Land degradation (Jetse) • Tipping points in ecology (Claudius) • Economic development and poverty traps (Paul) • Social changes (Maja, Jasper)	All
10:15	Coffee / Tea	All
10:45	**Assignment 3.5:** Interpretation and analysis	Groups
12:30	Lunch	All
13:30	Group work continued, prepare presentation	Groups
15:00	Tea break	All
15:30	Presentations	Groups
17:30	Free time	All
19:00	Dinner	All
20:00	Free evening	All

Date/Time	Activity	Who?
Saturday 2 May	**Day for own work**	
8:00	Breakfast	All
10:00	Free day for own work and catching up of reading and group work where needed	
11:00	Coffee break	
12:30	Lunch	
15:00	Tea break	
19:00	Dinner	
Sunday 3 May	Day off, excursion to national park	
7:00 ??	Breakfast and get take-away lunch	
Monday 4 May	**Assignment 4: Modelling complex systems**	
7:30	Breakfast	All
8:30	Lecture: Introduction to models (link to what has been done so far) • Land degradation models • Farming system models • Fuzzy cognitive maps	 Lieven Maja / Paul Jetse
9:30	**Assignment 4.1:** Develop a simulation model	Groups
10:00	Coffee break	All
10:30	**Assignment 4.1** continued	Groups
12:30	Lunch	All
13:30	**Assignment 4.1** continued	Groups
15:00	Tea break	All
15:30	**Assignment 4.1** continued	Groups
17:00	Feedback Session with lecturers: Each group shares with lecturers where they stand with respect to their model	Groups
17:30	End of programme	
19:00	Dinner	All
20:00	Preparations final fieldwork for the model.	Groups

Date/Time	Activity	Who?
Tuesday 5 May	**Fieldwork**	
7:30	Breakfast, get take-away lunch	All
8:30	**Assignment 4.2:** Remaining gaps	Groups
12:30	Lunch in the field including: • Reflection on morning session • Possible adjustments of plan of action	All
13:30	Field work continued	Groups
17:00	Travel back / Free time	All
19:00	Dinner	All
20:00	Free evening	All
Wednesday 6 May		
7:30	Breakfast	All
8:30	**Assignment 4.3:** Fine-tune, reflect and preparation presentation	Groups
10:00	Coffee break	All
10:30	Group presentation (15 minutes) and discussion (15 minutes)	All
12:30	Lunch	All
13:30	<u>Group discussion</u> Interactions between study area's: Groups discuss how their area are linked (bio-physical and socio-economic)	Groups
15:00	Tea break	All
16:00	<u>Group work:</u> Writing phase and first conclusions	Groups
17:30	Drinks and free time	All
19:00	Dinner	All
20:00	Informal group work activities	Groups

Date/Time	Activity	Who?
Thursday 7 May	**Assignment 5: Scenario analysis**	
7:30	Breakfast	All
8:30	Debate: Scenario analysis • Climate change (Lieven) • Ecosystem services (Monique) • Integrated assessments (Jetse) • Scenario's for land use planning (Jasper)	All
10:00	Coffee Break	All
10:30	**Assignment 5.1:** Define policy question	Groups
12:30	Lunch	All
13:30	**Assignment 5.2:** Develop scenarios	Groups
15:00	Tea break	All
15:30	**Assignment 5.2:** Continued / preparing short presentation.	Groups
17:00	Presentation Scenario's	All
19:00	Diner	All
20:00	Free evening	All
Friday 8 May	**Finalising and Presentation**	
7:30	Breakfast	All
8:30	Final preparations of presentation	Groups
10:00	Coffee break	All
10:30	Presentations (30 min. per group) and 15 min. questions	All
12:30	Lunch	All
13:30	Presentations continued	All
15:00	Tea Break	All
15:30	**Assignment 6:** Discussion and conclusions	All
17:00	End of course	All
18:00	Course dinner and Party	All
Saturday 9 May		
9:00	Breakfast	All
	Departure	

7. List of Participants

#	Name	Research Group / Chair Group	Institute / University	Email address
1	Mary Antwi	Soil Science	Kwame Nkrumah University of Science and Technology	martwi2007@yahoo.com
2	Alimata Bandaogo	Natural Resources Management and Crop Production	Institute of Environmental and Agronomic Research/ Burkina Faso	limbandaogo@yahoo.fr
3	Astrid Bos	Laboratory of Geo-information Science and Remote Sensing	Wageningen University	astrid.bos@wur.nl
4	Greta van den Brand	Plant Production Systems	Wageningen University	gretaj.vandenbrand@wur.nl
5	Rockefeller Erima	Soil Geography and Landscape	Wageningen University	rockefeller.erima@wur.nl
6	Chantal Hendriks	Soil Geography and Landscape	Wageningen University	chantal.hendriks@wur.nl
7	Ali Ibrahim	Crop and Soil Sciences	Kwame Nkrumah University of Science and Technology(KNUST)	ibramali@myway.com
8	Matema Imakumbili	Soil Science Department	Sokoine University of Agriculture	imakumbili@gmail.com
9	Konstantin Ivushkin	Laboratory of Geo-information and Remote Sensing	Wageningen University	konstantin.ivushkin@wur.nl
10	Daniel Jaleta Negasa	Soil Science	Sokoine University of Agriculture	danieljaleta1@yahoo.com
11	Isaac Jonathan Jambo	Farming Systems Ecology	Wageningen University	isaac.jambo@wur.nl
12	Jacob Kaingo	Department of Agricultural Engineering and Land Planning	Sokoine University of Agriculture	jacobkaingo@gmail.com
13	Ni'matul Khasanah	Plant Production System	Wageningen University	nimatul.khasanah@wur.nl
14	Samuel Kinyanjui	Plant Production Systems	Wageningen University	samuel.kinyanjui@wur.nl
15	Aliou Badara Kouyate	Laboratoire Sol Eau Plante Institut d'Economie Rural (IER)/ Mali	Kwame N'Krumah University of Science and Technology (KNUST)	aloubadarakouyate@yahoo.fr
16	Maricke van Leeuwen	Soil Geography and Landscape	Wageningen University	maricke.vanleeuwen@wur.nl
17	Janet Nabwami	Soil Science	Sokoine University of Agriculture, Tanzania	janettegem@gmail.com

#	Name	Research Group / Chair Group	Institute / University	Email address
18	Abebe Nigussie Nigatu	Plant and Soil Science	University of Copenhagen	nigatu@plen.ku.dk
19	Anthony Oyoo	Soil Geography and Landscape	Wageningen University	a.oyoo@cgiar.org
20	Austin Phiri	Soils and Agricultural Engineering Commodity Group	Bvumbwe Agricultural Research Station, Ministry of Agriculture and Food Security	phiriaustin534@gmail.com
21	Minke Stadler	Farm Systems Ecology	Wageningen University	minke.stadler@wur.nl
22	Simone Verkaart	Development Economics	Wageningen University	s.verkaart@cgiar.org
23	Jannike Wichern	Plant Production Systems	Wageningen University	jannike.wichern@wur.nl
24	Rebecca Yegon	Engineering and Land Planning	Sokoine University of Agriculture	beckykiptoon@yahoo.com

8. List of Organisers / Lecturers

Name	Role	Subject	E-mail address
Claudius van de Vijver	Coordinator, Lecturer	Ecology	claudius.vandevijver@wur.nl
Monique Gulickx	Coordinator, Lecturer	Land use	monique.gulickx@wur.nl
Iris van der Meer	Course assistant	Ecology	Iris.vandermeer@wur.nl
Lieven Claessens	Logistics, Lecturer	Geology	lieven.claessens@wur.nl
Jetse Stoorvogel	Lecturer	Soil / land use	jetse.stoorvogel@wur.nl
Maja Slingerland	Lecturer	Agro-systems	Maja.slingerland@wur.nl
Jasper de Vries	Lecturer	Governance / land use	Jasper.devries@wur.nl
Paul Ingenbleek	Lecturer	Economy and markets	paul.ingenbleek@wur.nl

9. Poster session

- Participants and course leaders present themselves via the submitted poster.
- Each session lasts 15 minutes (2 minutes presentation and 10 minutes discussion and 3 minutes selection for next session).
- Participants select posters based on the poster schedule below

Session 1

#	Name	Title Poster
1	Alimata Bandaogo	Nitrogen use efficiency of irrigated rice as affected by the type of urea fertilizers and soil properties in Burkina Faso
7	Ali Ibrahim	Exploring the options for improving yields and resource use efficiency in the Sahelian low-input farming system
13	Ni'matul Khasanah	Oil palm (*Elaeis guineensis*) production in Indonesia: agronomic options to reduce the carbon footprint for smallholder production systems
19	Anthony Oyoo	Landscape level CSA systems trade-off analysis: Biophysical outcomes vis-a-vis distributional socio-economic impacts
25	Claudius van de Vijver	Sustainability of Savanna Ecosystems
31	Jasper de Vries	Understanding governance interactions for planned and unplanned spatial change

Session 2

#	Name	Title Poster
2	Mary Antwi	Geospatial analysis of major soil nutrients within integrated soil fertility management options in the northern region of Ghana
8	Matema Imakumbili	High cassava cyanogenic glucosides levels in Mtwara: The Role of soil fertility
14	Samuel Kinyanjui	The role of geo spatial data in up-scaling the applicability of site specific nutrient recommendation tools in sub-Saharan Africa: Moving decision support tools from research to development
20	Austin Phiri	Improving nitrogen use efficiency by maize through the pigeon pea-groundnut intercrop-maize rotation cropping system in Malawi
26	Monique Gulickx	Integration of science, policy and practice for a sustainable future
32	Paul Ingenbleek	Development Marketing

Session 3

#	Name	Title Poster
3	Astrid Bos	Zooming in on the forest Multi-scale and interdisciplinary monitoring of forest changes for REDD+
9	Konstantin Ivushkin	Developing Remote Sensing and GIS approach for soil salinity assessment in relation to agriculture

15	Aliou Badara Kouyate	Optimizing Tilemsi phosphate rock application to enhance soil phosphate availability for crop production in Sahelian zone of Mali.
21	Minke Stadler	Understanding mind-set and socio--cultural aspects that influence the relations between nutritious food production and landscape
27	Iris van der Meer	Research management and conservation ecology

Session 4

#	Name	Title Poster
4	Greta van den Brand	Working in N2Africa
10	Daniel Jaleta Negasa	Land cover dynamics effects on hydrological process at watershed scale in central Ethiopia
16	Maricke van Leeuwen	Visual soil assessment (VSA) for improved farm and ecosystem management
22	Simone Verkaart	The potential contribution of agricultural technology transfer interventions to poverty reduction in East-Africa
28	Lieven Claessens	System approaches to understand and improve smallholder agricultural systems in Sub-Saharan Africa

Session 5

#	Name	Title Poster
5	Rockefeller Erima	Agro-ecological diversity as a tool to reduce soil-borne diseases in plants
11	Isaac Jonathan Jambo	Heterogeneities in Smallholder Farming Systems: Determinants and Effects
17	Janet Nabwami	Effects of multi nutrient super granules on lowland and upland rice yields in Eastern and Northern Uganda
23	Jannike Wichern	Food Security in East Africa - from Farm Household to the Region
29	Jetse Stoorvogel	The feedbacks between soils and land use

Session 6

#	Name	Title Poster
6	Chantal Hendriks	The challenges with soil data in regional land-use analysis
12	Jacob Kaingo	Modelling spatial variability of soil hydraulic properties in an agricultural watershed in Tanzania
18	Abebe Nigussie Nigatu	Nitrogen turnover and loss during composting of biodegradable waste
24	Rebecca Yegon	Investigating planting pits water and nutrient productivity in a sorghum pigeon pea rotation in Semi-arid Eastern Kenya
30	Maja Slingerland	How can smallholders grasp opportunities?

B: Definitions and concepts

1. Important definitions

Land dynamics
Land dynamics can be defined as the change in physical, environmental and socio-economic aspects of the land and their multi-scale interactions. More specifically it relates to the rates and states of system components as:

- Land use
- Livelihoods
- (Soil) Fertility
- Degradation (consequences of the use on land stability): Water, Soil and nutrients, species diversity, vegetation cover
- (Bio)diversity (species diversity / arrangement of the system / agro-biodiversity and the change in time)
- Governance
- Networks (level of exchange with the in- and outside world)

Multidisciplinarity
Multidisciplinarity is the act of joining together two or more disciplines without integration. Each discipline yields discipline specific results while any integration would be left to a third party observer. An example of multidisciplinarity would be a panel presentation on the many facts of the AIDS pandemic (medicine, politics, epidemiology) in which each section is given as a stand-alone presentation.

A multidisciplinary community or project is made up of people from different disciplines and professions who are engaged in working together as equal stakeholders in addressing a common challenge. The key question is how well can the challenge be decomposed into nearly separable subparts, and then addressed via the distributed knowledge in the community or project team. The lack of shared vocabulary between people and communication overhead is an additional challenge in these communities and projects. However, if similar challenges of a particular type need to be repeatedly addressed, and each challenge can be properly decomposed, a multidisciplinary community can be exceptionally efficient and effective. A multidisciplinary person is a person with degrees from two or more academic disciplines, so one person can take the place of two or more people in a multidisciplinary community or project team. Over time, multidisciplinary work does not typically lead to an increase nor a decrease in the number of academic disciplines.

Interdisciplinarity
"Interdisciplinarity" in referring to an approach to organising intellectual inquiry is an evolving field, and stable, consensus definitions are not yet established for some subordinate or closely related fields.

An interdisciplinary community or project is made up of people from multiple disciplines and professions who are engaged in creating and applying new knowledge as they work together as equal stakeholders in addressing a common challenge. The key question is what new knowledge (of an academic discipline nature), which is outside the existing disciplines, is required to address the challenge. Aspects of the challenge cannot be addressed easily with existing distributed knowledge, and new knowledge becomes a primary sub-goal of addressing the common challenge. The nature of the challenge, either its scale or complexity, requires that many people have interactional expertise to improve their efficiency working across multiple disciplines as well as within the new interdisciplinary area. An interdisciplinary person is a person with degrees from one or more academic disciplines with additional interactional expertise in one or more additional academic disciplines, and new knowledge that is claimed by more than one discipline. Over time, interdisciplinary work can lead to an increase or a decrease in the number of academic disciplines.

Alternative stable state theory

Alternative stable state theory was first proposed by Lewontin (1969), but other early key authors include Holling (1973), Sutherland (1974), May (1977), and Scheffer et al. (2001).

In the broadest sense, alternative stable state theory proposes that a change in (eco)system conditions (gradual direct perturbation) can result in an abrupt shift in the state of the system, such as a change in population or community composition. Alternative stable state theory suggests that discrete states are separated by ecological *thresholds*, a level of a variable that, when passed, results in a shift from one state to the other. Because systems are resistant to state (phase or regime) shifts, due to feedbacks, significant perturbations are usually required to overcome ecological thresholds and cause shifts from one stable state to another. The resistance to state shifts is known as *resilience* (Holling 1973, see below).

Hysteresis

Hysteresis is an important concept in alternative stable state theory. It implies that given the same environmental conditions different stable states of the system can exist. Hence, when a system has shifted from state A to B as result of perturbation in an environmental variable, return to state A does not necessarily occur when the variable is brought back to its original level. A real-world example of hysteresis is helpful to illustrate the concept. Coral reef systems can dramatically shift from pristine coral-dominated systems to degraded algae-dominated systems when populations grazing on algae decline. The 1983 crash of urchin populations in Caribbean reef systems released algae from top-down (herbivory) control, allowing them to overgrow corals and resulting in a shift to a degraded state. When urchins rebounded, the high (pre-crash) coral cover levels did not return, indicating hysteresis (Mumby et al. 2007).

Resilience

Resilience is defined as "the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes". A resilient system can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future." Resilience is conferred in human and ecological systems by adaptive capacity.

By their very nature, basins of attraction display resilience. Ecosystems are resistant to state shifts – they will only undergo shifts under substantial perturbations – but some states are more resilient than others. In the ball-and-cup model, a valley with steep sides has greater resilience than a shallow valley, since it would take more force to push the ball up the hill and out of the valley. Resilience can change in stable states when environmental parameters are shifted. Often, humans influence stable states by reducing the resilience of basins of attraction. There are at least three ways in which anthropogenic forces reduce resilience (Folke et al. 2004)

(1) Decreasing diversity and functional groups, often by top-down effects (e.g., overfishing)
(2) altering the physico-chemical environment (e.g., climate change, pollution, fertilization)
(3) modifying disturbance regimes to which organisms are adapted (e.g., bottom trawling, coral mining, etc.)

When the resilience is decreased, ecosystems can be pushed into alternative, and often less-desirable, stable states with only minor perturbations. When hysteresis effects are present, the return to a more-desirable state is sometimes impossible or impractical (given management constraints). Shifts to less-desirable states often entail a loss of ecosystem service and function, and have been documented in an array of terrestrial, marine, and freshwater environments (reviewed in Folke et al. 2004).

Ecosystem
An ecosystem is a community of living organisms (plants, animals and microbes) in conjunction with the non-living components of their environment (things like air, water and mineral soil), interacting as a system with internal regulation through sub-system feedback mechanisms. These biotic and abiotic components are regarded as linked together through nutrient cycles and energy flows. As ecosystems are defined by the network of interactions among organisms, and between organisms and their environment, they can be of any size but usually encompass specific, limited spaces (although some scientists say that the entire planet is an ecosystem).

Agro-ecosystems
special type of ecosystem: more open (large flows of inputs and outputs), less diversity (due to selection of desired species), and strong external regulation (by management).

Hierarchy
Hierarchy deals with ranking, higher levels rule or constrain and often contain lower levels. a lower unit is subordinate to a higher one, whereas within a level no subordination exists. Cropping systems and animal production systems are for instance subsystems of farming systems.

Farming system
A combination of cropping systems and animal production systems and their interactions managed by a household, using its internal resources (labor, land) and external inputs to produce certain (desired and undesired) outputs. The farm household, the main actor at this level, integrates agronomic, economic and social objectives, to arrive at specific management practices and specific livelihood outcomes.

Cropping system
A field comprising soil, crop, weed, pathogen and insect subsystems that transform solar energy, water, nutrients, labour and other inputs into food, fuel, fibber and pharmaceuticals. A cropping systems has a spatial component (mono or mixed) and a temporal component (fallow systems, crop rotations).

Agronomy
The application of scientific principles to the cultivation of land, the study of effects of management practices, such as cultivation measures, on biophysical processes determining the performance of agro-ecosystems.

Principles of production ecology: production levels, factors and processes
<u>Production levels</u> (from principles of production ecology):
- potential (unlimited) production as defined by crop characteristics, CO_2, radiation and temperature. (At full ground cover, the growth rate of a crop is typically between 150 and 350 kg ha^{-1} day^{-1} of dry matter)
- attainable production is production only limited by water or nutrients.
- actual production is production limited by water and nutrients and reduced by effects of weeds, pests, diseases and pollutants.

<u>Production processes:</u> Photosynthesis, CO2 assimilation, respiration for maintenance and growth, evaporation and transpiration.

Data
Data have a spatial (location), a thematic (attribute), a time and a quality component.

Data quality
Data quality can be assessed in terms of accuracy (degree of accordance with true values), precision (numbers of decimals) and reliability (truthfulness).

2. Systems approach

A system can be defined as a limited part of reality that contains interrelated *elements*. Examples of systems are the leaf of a plant, the human body, a fish pond or the earth. The totality of the relations within systems is known as the *system structure*. If we want to analyse a system, we have to decide which part of reality we want to address. The definition of a system as given above therefore implies that a *boundary* has to be chosen. The boundaries separate the system from inputs and outputs from a larger world. It is wise to select the boundary so that the system is isolated from its environment. This is hardly ever possible, but then it should be attempted to follow this rule.
A systems consists of five elements: *components* (or sub-systems)*, interactions between components* (i.e. structure), *boundaries, inputs* and *outputs*

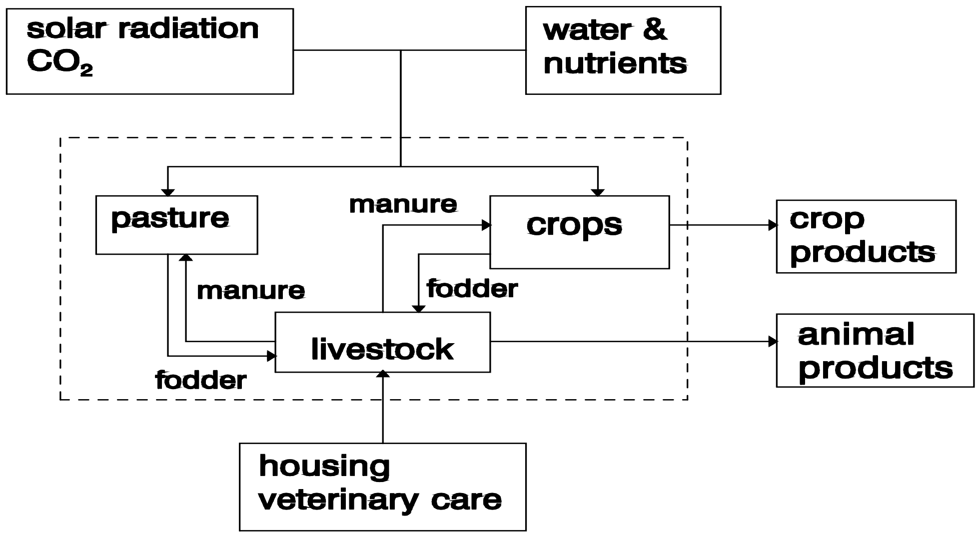
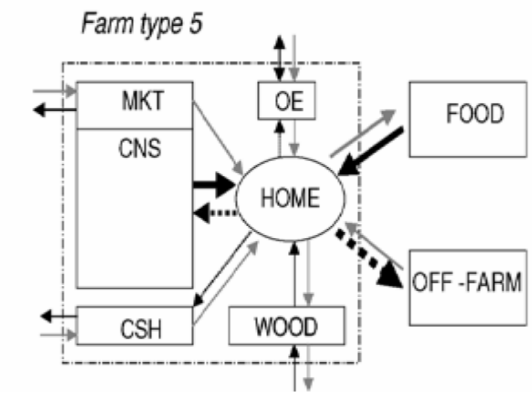


Figure 1: A model of an agricultural system with its elements (boxes), structure (arrows) its boundary (dotted line), inputs and outputs (boxes outside system boundary)

In figure 1, the research question could be about nutrient flows in manure and fodder at the farm level (arrows, e.g. in kg Phosphorus) ending up in crop and animal products leaving the farm. When the research question would be about farm income the boxes may be different (Figure 2), farm household needs to be included (home) and the arrows would represent money (euro). Flows are all expressed in a similar unit that is closely related to the research topic.



HOME= household (family size)
MKT = surplus of food crop produce sold on the market
CNS = food crops consumed by the household
CSH = cash crops
OE = other enterprises, e.g. income generating activities that involve on-farm production factors
WOOD = woodlot, mainly for fuel
FOOD = external source of food items (market)
OFF-FARM = external source of income

Figure 2: Household model in Kenya (P. Tittonell et al. / Agriculture, Ecosystems and Environment 110 (2005) 149–165)

From a philosophical point of view it is debatable whether a system is an entity that really exists, or whether it is a construct of the human mind to be able to deal with a certain problem. We will use a pragmatic approach, and use the concept 'system' because it can help us to address real-life problems and to increase our understanding of the functioning of the outside world. The research questions we ask, will determine the definitions of the system, its elements, its structure and its boundaries.

System Analysis

Systems analysis is both a philosophical approach and a collection of techniques, including simulation, developed explicitly to address problems dealing with systems. Systems analysis emphasizes the use of mathematical models to identify and simulate important characteristics of systems.

3. Spatial and temporal scales

Scale usually refers to the spatial or temporal dimension of a phenomenon, and scaling is the transfer of information between scales. Scale is about size, either relative or absolute, and involves a fundamental set of issues. Scale can refer to spatial temporal and thematic scales. Temporal scale deals with the size of time units, thematic scale with the grouping of entities or attributes such as people or weather variables. The concept of scale can be confusing, insofar as it has multiple referents. Cartographic scale refers to the depicted size of a feature on a map relative to its actual size in the world. Analysis scale refers to the size of the unit at which some problem is analysed, such as at the county or state level. Phenomenon scale refers to the size at which human or physical earth structures or processes exist, regardless of how they are studied or represented. Although the three referents of scale frequently are treated independently, they are in fact interrelated in important ways that are relevant to all scientists

The concepts of scale can be very different. We can refer to conceptual scales dealing with either countries, districts, or watersheds or we can refer to maps. The conceptual scales can be dealt with in different ways but often we see differences between disciplines due to the subject of research (e.g. biophysical or administrative hierarchies in the region) In the case of maps vector maps or grid maps need to be separated.
For the ease of the discussion we will look at the case of a polygon map while discussing the vector maps. Similar concepts apply if we deal with points or lines. The scale of vector maps typically is linked to a physical, printed map. This is also the original definition of scale. The scale of a map is defined as the ratio of a distance on the map to the corresponding distance on the ground. Maps are often described as small scale (e.g., regional maps) showing large areas of land on a small map, or large scale, showing smaller areas in more detail, typically for farms or town plans. Whereas the scale of a physical map provides useful information on a map, its definition has become slightly

problematic with the introduction of GIS where maps can be represented at different scale levels. In GIS, the original scale of the map provides information on the scale level at which the original data are described. One should be careful to increase the map scale and present the maps at scales for which they were not made. The scale of the vector maps is determined by its extent and the level of detail in the map. The latter can be seen as the resolution of vector based maps, which is difficult to define. It corresponds to the scale at which the original map is created (which could be linked to the original sampling density as shown in the case of soil survey below). One can also derive the resolution from the point density that is used to define lines in these vector maps. Although technically vector maps can be blown up to larger scales or presented at smaller scales, we are facing a number of limitations. Blown up maps are simply not made for those scales which will result in a pretence of accuracy that typically does not correspond the inventory techniques that were used. Reducing the scale of maps on the other hand creates a problem with the readability of the map. The lines of the map need to be generalized and adapted to the other scale level. In this context it is important that each scale level has a minimum size delineation being the smallest size of a delineated area on the map. Different definitions of the minimum size delineation do exist. A scale-independent rule of thumb is that the minimum size delineation is roughly $0.5cm^2$ on the final printed map. This means that, for example, the minimum size delineation is 50ha on a 1:100,000 scale map. Roughly three general map scales can be identified:

- Exploratory survey: surveys with a low survey intensity often with scales of 1:250,000 or more general
- Reconnaissance survey: surveys with an intermediate survey intensity with scales between 1:25,000 and 1:250,000.
- Detailed survey: Surveys with an high survey intensity at scales of 1:25,000 or more detailed.

Originally, the surveys were carried out with limited legacy or auxiliary data. The scale levels were therefore often linked to a certain sampling density. With an increasing use of the legacy and auxiliary data, the required sampling density became more variable. The scale of a grid map is defined by the scale trilogy: map extent – map resolution – support. The map extent is the area covered by the map. The resolution is the density of observations or grid cells. The support of the observations is the area that a single observation refers to (e.g., a point, a field, or a 10 ha block).

Concepts of spatial scales can easily be transferred to temporal scales where we also deal with the trilogy of the period, interval, and support of the observations. Also here different disciplines will develop their own hierarchy which could be based on certain processes (growing seasons) or other elements (e.g., the fiscal year).

4. Networks, actors and institutions

Networks

Network theory is based upon the idea that everybody is connected with each other through networks. These networks consist of people or actors, which are connected in various ways. An important characteristic is there is no centre, no beginning and no end. Good examples are social networks, through sites as Facebook, twitter or LinkedIn people are connected with each other. However, people are also part of networks through others they know professionally, through hobby clubs or vulnerary work. This does not mean that being part of a network is a deliberate choice, networks emerge and evolve aware and unaware. Some networks are visible from the outside and rather stable, and are therefore often seen as a group, for instance farmer networks. Others are less visible and rather variable, groups of friends for instance.

Networks contain more than actors alone. Networks also include areas, concepts, objects etc. People in a network can have certain important meeting places and understandings of what values are or important buildings. These elements are often characteristic to a certain network, and actors in networks can associate themselves with these. For instance, networks of people providing care for fellow villages associate themselves with the village, and value of taking care of others.

Actors
On the one hand, in networks not everybody is seen as part of the network, while on the other hand everybody is part of several networks. This situation is not stable, networks change constantly. As people are part of several dynamic networks, different types of networks are connected and the exact border is impossible to establish. As a result, traveling through networks of actors, the importance of objects, places and values slowly changes. In networks actors can have various roles, think about follower, enabler, booster etc.

Institutions
Due to their characteristics, networks are considered as complex. However, in networks many interactions take place and resources flow through networks (e.g. information, farming materials, food). These interactions and flows are structured by institutions. Institutions can be seen as collectively agreed sets of rules making it easier for resources to flow through networks and to enable interactions. These can be formal and written down, such as laws or as formal rules in a community. Others are informal and are an alternative for formal institutions.

5. Models

Models are simplified or abstracted representations of a system. A model can for instance be a drawing, a map, a statistical or a mathematical model. Every field of work has its own codes to represent a system in the form of a model. The system of a radio can for instance be represented by a code used by electricians or by a picture of a radio (Figure 3).

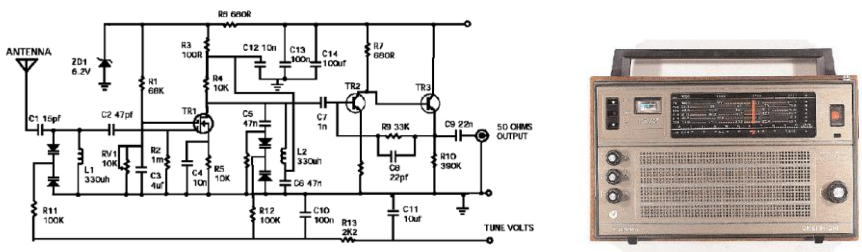


Figure 3: System of a radio: represented by a code used by electricians (left) or by a picture of a radio (right)

Models can be used to simulate the behaviour of systems. The definition of *simulation* is the building of mathematical models and the study of their behaviour. This behaviour can be the development of the system in time.

Models that describe systems that change in time are called *dynamic models*. The opposite of a dynamic model is a *static model*. An example of a static model is the calculation of the light distribution over the leaves of vegetation from the canopy architecture, reflection and transmission of the leaves, solar position, and the brightness of the sky. The results of the calculations performed with these static models or the models themselves, often form a part of dynamic models.

Descriptive models show the existence of relations between the elements of a system without any explanation. Statistical models that summarize some of the interrelations of system components are examples of these. *Explanatory* models on the other hand explain. Explanatory models are often used in biology because various levels of organisation are distinguished by the level of integration at which the processes occur. The different levels of integration may be classified according to the size of the system, such as molecules, cell structures, cells, tissues, organs, individuals, populations, communities and ecosystems.

Explanatory models demand that research has to be carried out for at least two integration levels. The lower integration level will then be the explanatory level and the upper level is the one to be explained. In this way, one might attempt to derive the characteristics of membranes from the characteristics of the molecules of which they consist, or one might try to explain the processes in an ecosystem on the basis of knowledge of the behaviour and physiology of the constituent species. Explanatory models can be both *static* and *dynamic*. An example of a static model is one in which the connection between respiration and growth of organisms is calculated on the basis of knowledge of the biochemical processes involved. The time-dependent dimension of the system behaviour is ignored. An example of a dynamic model is a crop growth model in which plant phenology and biomass production are modelled based on climate and soil input. In a dynamic model the changes in the states of the system are described over time.

Models are increasingly used in environmental sciences, because they are one of the few tools that are able to relate quantitatively the impact on a landscape with the consequences for its state. Landscapes are extremely complex, and so it is an overwhelming task to predict environmental effects. It is here that the model comes into the picture. With sound process based knowledge it is possible to extract the features of the landscape that are involved in the problem under consideration

An environmental model focuses on the objects of interest for the considered problem. It would disturb the main objectives of a model to include too many irrelevant details. There are many different environmental models of the same system, as the model edition is selected according to the model goals.

In its mathematical formulation, a model has five components:
1. Forcing functions, or external variables, which are functions or variables of an external nature that influence the state of the system. In a management context the problem to be solved can often be reformulated as follows: if certain forcing functions are varied, how will this influence the state of the system? The model is used to predict what will change in the system, when forcing functions are varied with time.

2. State variables describe, as the name indicates, the state of the system. The selection of state variables is crucial to the model structure, but sometimes the choice is obvious. When the model is used in a management context, the values of state variables predicted by changing the forcing functions can be considered as the results of the model, because the model will contain relations between the forcing functions and the state variables.

3. Mathematical equations are used to represent the biological, chemical and physical processes. They describe the relationship between the forcing functions and state variables, and between the state variables. The same type of process may be found in many different environmental contexts, which implies that the same equations can be used in different models. This does not imply, however, that the same process is always formulated by use of the same equation. First, the considered process may be better described by another equation because of the influence of other factors. Second, the number of details needed or wanted to be included in the model may be different from case to case due to a difference in complexity of the system or/and the problem. Some modellers refer to description and mathematical formulation of processes as submodels.

4. Parameters are coefficients in the mathematical representation of processes. They may be considered constant for a specific system. In causal models the parameter will have a scientific definition, e.g. the excretion rate of cadmium from a fish. Many parameters are not indicated in literature as constants but as ranges, but even that is of great value in the parameter estimation, as will be discussed further in the following text. Our limited knowledge of parameters is one of the weakest points in modelling as will be touched on often throughout the chapter. Furthermore, the application of parameters as constants in our models is unrealistic due to the many feed-backs in real ecosystems. The flexibility of ecosystems is inconsistent with the application of constant parameters in the models. A new generation of models that attempts to use parameters varying according to some ecological principles seems a possible solution to the problem, but a further development in this direction is absolutely needed before we can achieve an improved modelling procedure reflecting the processes in real ecosystems.

5. Universal constants, such as the gas constant and atomic weights, are also used in most models.
Models can be defined as formal expressions of the relations between essential elements of a problem in mathematical terms. The first recognition of the problem is often verbal. This may be recognized as an essential preliminary step in the modelling procedure, which will be treated in more detail in the next section. The verbal model is, however, difficult to visualize and it is, therefore, more conveniently translated into a conceptual diagram, which contains the state variables, the forcing function and how these components are interrelated by mathematical formulations of processes.

The forcing functions are: out- and inflows, concentrations of nitrogen components in the in- and outflows, solar radiation, and the temperature, which is not shown on the diagram, but that influences all the process rates. The arrows in the diagram illustrate the processes, and they are formulated by use of mathematical expressions. Four significant steps in the modelling procedure should be defined in this section. They are verification, sensitivity analysis, calibration and validation:

Verification is a test of the internal logic of the model. Typical questions in the verification phase are: Does the model react as expected? Is the model stable in the long run? Does the model follow the law of mass conservation? Verification is largely a subjective assessment of the behaviour of the model. To a large extent the verification will go on during the use of the model before the calibration phase, which has been mentioned above.

Sensitivity analysis follows verification. Through this analysis the modeller gets a good overview of the most sensitive components of the model. Thus, sensitivity analysis attempts to provide a measure of the sensitivity of either parameters, or forcing functions, or submodels to the state variables of greatest interest in the model. If a modeller wants to simulate a toxic substance concentration in, for instance, carnivorous insects as a result of the use of insecticides, he will obviously choose this state variable as the most important one, maybe in addition to the concentration of the toxic substance concentration in plants and herbivorous insects.

Calibration is an attempt to find the best accordance between computed and observed data by variation of some selected parameters. It may be carried out by trial and error, or by use of software developed to find the parameters giving the best fit between observed and computed values. In some static models and in some simple models, which contain only a few well-defined, or directly measured, parameters, calibration may not be required.

Validation must be distinguished from verification. Validation consists of an objective test on how well the model outputs fit the data. The selection of possible objective tests will be dependent on the scope of the model, but the standard deviations between model predictions and observations and a comparison of observed and predicted minimum or maximum values of a particularly important state variable are frequently used. If several state variables are included in the validation, they may be given different weights.

6. Scenarios

Hypothetical, possible future pathways that describes dynamic processes and represent sequences of events over a period of time, including causally related states, driving forces, events, consequences and actions. The word scenario comes from the dramatic arts. In the theater, it is an outline of the plot; for a movie, a scenario sets forth details relevant to the plot. Its formal intellectual roots trace back to the Manhattan project six decades ago when world-renowned nuclear physicists explored and evaluated the possibility that the energy build-up from a full-scale explosion of the hydrogen bomb, that ignite a devastating deuterium reaction in the skies and the oceans. In the 1950s, Herman Kahn and Anthony Weiner at the Rand Corporation used the concept of scenarios in a series of strategic studies for military planning purposes. In the corporate world, scenarios were refined at Royal Dutch/Shell in the 1970s and 1980s, and Shell became a leader of the scenario approach to business planning. The word scenario came to the attention of the general public in 1972 with the publishing of The Limits to Growth by Dennis Meadows and colleagues. Today, scenario development is used in a variety of different contexts ranging from political decision making, to business planning, to local community management, to global environmental understanding.

Garry Peterson and colleagues provide a good first point of entry to define a scenario. They propose to position scenarios along two axes: the degree of uncertainty and the degree to which a system can be controlled. As depicted in the figure, scenarios are useful in systems where uncertainty is high and controllability low. Most definitions of scenarios are in agreement with this assumption. However, the highest level of agreement is on what a scenario is not. A scenario is not a prediction, understood as the best possible estimate of future developments; neither is a scenario a forecast, the best estimate from a particular method or model. Lastly, a scenario is also not a projection, as it depends on assumptions about drivers and leads to “what if” type of statements.

A first definition of a scenario states that scenarios are hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision-points. Alternatively, scenarios can be defined as plausible, challenging, and relevant stories about how the future might unfold that can be told in both words and numbers, as done by the Millennium Ecosystem Assessment.

A large diversity of types of scenarios has been developed, and various attempts to classify them have been undertaken. For example, a classification based on degree of complexity, exploration versus decision support, and degree of formalization. Other useful classification criteria include forecasting versus backcasting, or whether participatory methods are employed. Within the framework of land use/cover related research, it is particular the division between qualitative and quantitative scenarios that is of interest.

Qualitative scenarios are usually in the form of narrative storylines and involves stakeholders during the development. Stakeholders can be involved in two fundamentally different manners, in-depth interviews and group sessions, or workshops. The advantages of interviews relate to a larger sample size, larger reproducibility and replicability and thus arguably enabling for a higher 'scientific' value, although the latter can be disputed. Nevertheless, there are important advantages of a workshop setting that outweigh the possible drawbacks. A group setting enables stakeholders to create a common vision; can be a stimulus for processes of social interaction and learning; is the ideal setting for development of complex, multidisciplinary scenarios; and might enable viewpoints that might not have been discovered in individual interviews. Given that participatory processes are at the heart of the development of qualitative scenarios, an important goal is usually related to the process itself. Stimulating discussion among stakeholders and initiating long-term participation in the decision-making process are often as important as the actual results of the exercise. The final output is usually in the form of a storyline, although similar methods are increasingly being employed for qualitative model building of which the output can be semi-quantitative, for example. Quantitative scenarios are almost always created to serve as an input into modelling. It therefore rarely serves as a product of its own. Of particular interest are area-based scenarios that are linked to spatially explicit models. Key questions are less related to how the future might unfold and more to where these changes will take place. Typical elements of area-based scenarios are the location of national parks; migration; or the construction of new roads. The focus of the model and therefore of the scenarios is on the distribution of land use. The availability of data can potentially limit the scope and richness of quantitative scenarios.

A particularly pressing issue is establishing the link between qualitative outputs from employing participatory methods and quantitative (i.e., data demanding) models. Many of the recent (global) scenario efforts – such as those of the Intergovernmental Panel on Climate Change, the United Nations Environment Programme and the Millennium Ecosystem Assessment – developed narrative storylines, that were subsequently quantified and linked to models. However, in most documented cases, the link between the stories and models remains rather rudimentary and both products are developed in parallel but separate exercises. Among the novel methods that have been employed is the use of agent-based models, that can be directly parameterized by stakeholders.

Another type of scenario that has increasingly been developed in recent years, is the multi-scale scenario. VISIONS and MedAction are good examples of how multi-scale scenarios can be developed using stakeholders and how decision support systems (DSS) can be used to quantify them. The Millennium Ecosystem Assessment has advocated a multi-scale approach as well in their conceptual framework that serves as the guidelines for a large number (>30) of sub-global assessments. The ultimate goal is to link a multitude of local studies, through a meso-level assessment that includes scenarios, to four global storylines.

Historically, land use (change) scenarios are mostly developed to serve as input for a land use change model. Therefore, most land use scenarios are quantitative rather than qualitative, although recently participatory methods are increasingly being employed to develop qualitative scenarios. As most currently available scenarios are linked to a model, they logically follow the framework of that model. The architecture of many land use models consists of two parts: a large-scale, non-spatial part where total quantities of each land use type are projected for a number of scenarios; and a small-scale spatially explicit part where those quantities are subsequently allocated. Land use scenarios therefore often have a place-based component.

Projections of large-scale developments are usually related to processes that are slower and act over large areas like climate change, macro-economic developments, or institutional factors like the expansion of the European Union. Depending on the spatial extent of the study area, these non-spatial aspects can be related to quantitative storylines. In most land use models these large-scale developments are a direct input in the allocation part of the model.

The future changes of all dynamic drivers of land use change that are spatially explicit are part of any land use scenario. Typical examples are the construction of a new road – linked to accessibility, the institutionalization of a national park, or migration patterns – linked to population density. Often, these place-based assumed changes will heavily influence resulting land use patterns.

Increasingly, scenarios are being recognized as one of the best tools in participatory approaches, like stakeholder workshops and focus groups. Discussion on possible futures is an excellent way to avoid conflict, increase awareness and start a process of mutual learning. It is therefore to be expected that the role of qualitative scenario development will increase in the coming decade. At the same time, DSSs have rapidly become easier to use, also by lay people. Top-down, bottom-up iterative procedures linking locally developed narratives and DDSs that can be discussed during series of stakeholder workshops could a great step forward.

PART C: Mount Kenya from different perspectives

1. Biophysical dimension

1.1 Geology

The geology of Kenya comprises of old rocks from the Precambrian ('basement' or 'shield') until the recent Quaternary. The Precambrian (>550Ma BP) basement rocks are metamorphic, folded, tilted, sheared and invaded by intrusive bodies. Palaeozoic (550-250 Ma BP) and Mesozoic (250-65 Ma BP) sedimentary rocks are present as north-south strips along the coast and have also been found at depth in the rift valley. During the Kenozoic (65 Ma BP to present), in the Mid-Tertiary, the Kenya dome started to uplift the surface (Figure 1). The rift valley formation initiated together with its associated tectonics and volcanism. Tertiary and Quaternary volcanic and intrusive rocks are present along a north-south band in the rift valley and along its both shoulders (Figure 2). Contemporaneous downwarp of the eastern part of the country allowed Kenozoic marine sediments to deposits only in East Kenya. The bigger part of the Kenozoic sediments are terrestrial (Mathu and Davies, 1996). Around Mount Kenya, the uplift has caused the river Tana to incise and form a terrace staircase. Recent uplift is 0.1-0.2 mm/a in the Embu region during the last 900k years, which is considerably faster than the average since the Mid-Pliocene (Veldkamp et al., 2007).

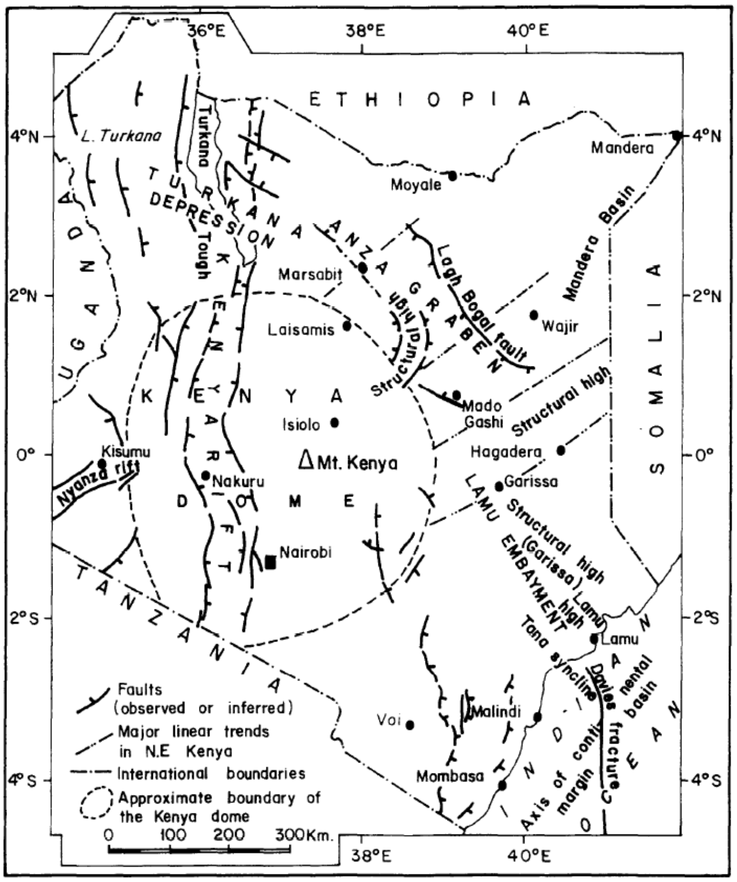


Figure 4: Simplified structural and tectonic map of Kenya (from Mathu and Davies, 1996).

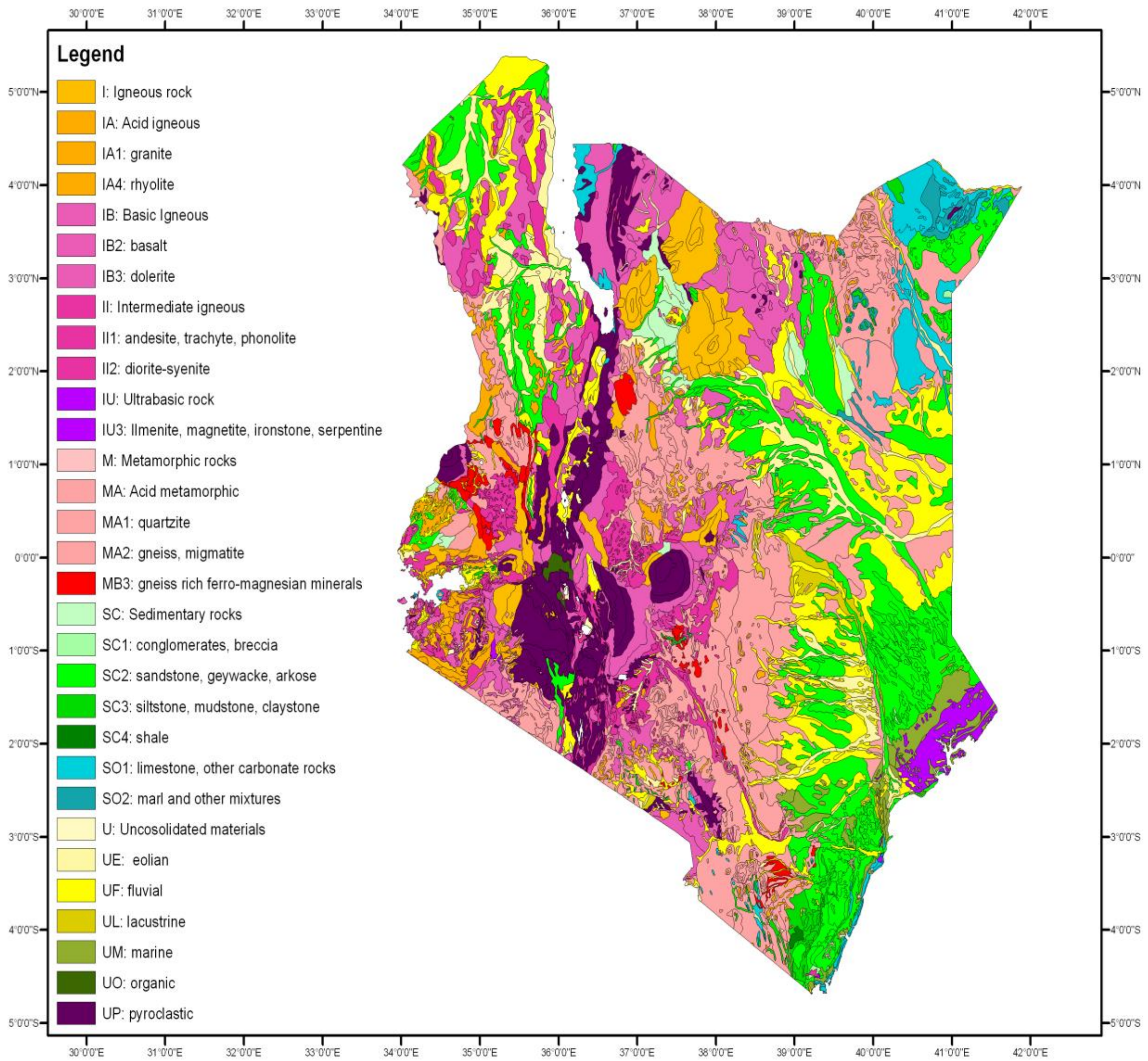


Figure 5: Lithological map of Kenya (Created from: ISRIC KENSOTER database, www.isric.org).

1.2 Geomorphology

Kenya consists of four main landscape types based on relief: the coastal and eastern plains, the central and western highlands, the rift valley basin and the Lake Victoria basin (Mathu and Davies, 1996). The Embu region at the eastern side of Mount Kenya is part of the central highlands. Geologically, it consists of two parts: the volcanic western part and the basement system eastern part. Along a big part the transition between these two areas is formed by a scarp. The high volcanic part is associated with rift valley formation and consists of volcanic deposits coming from the rift valley and Mount Kenya (lava flows, lahars, volcanic debris avalanches) (Figure 3). The formation of the rift valley and its associated volcanism have had a profound influence on the environment (climate, vegetation) and hominin evolution (Figure 4). The lower basement system part consists of Precambrian basement rocks which form part of the Mozambique belt. This landscape generally shows lower relief difference than the volcanic part. Landscape types include low level mountains, hills, uplands, minor scarps, plateaus and valleys (De Meester and Legger, 1988). Figure 5 shows a schematic overview of landscape units and their relation to soil units, which tentatively represents the lower part of the study area.

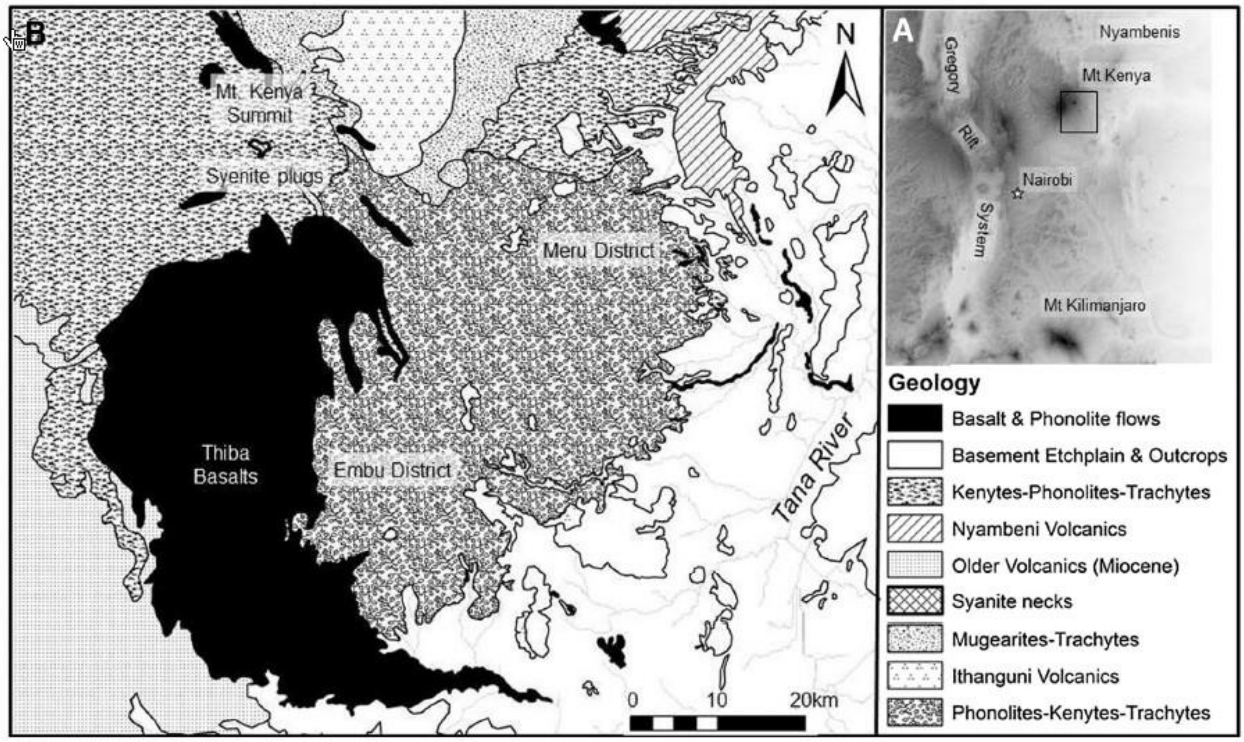


Figure 6: Simplified geological map of the Embu region. From Schoorl et al., 2014.

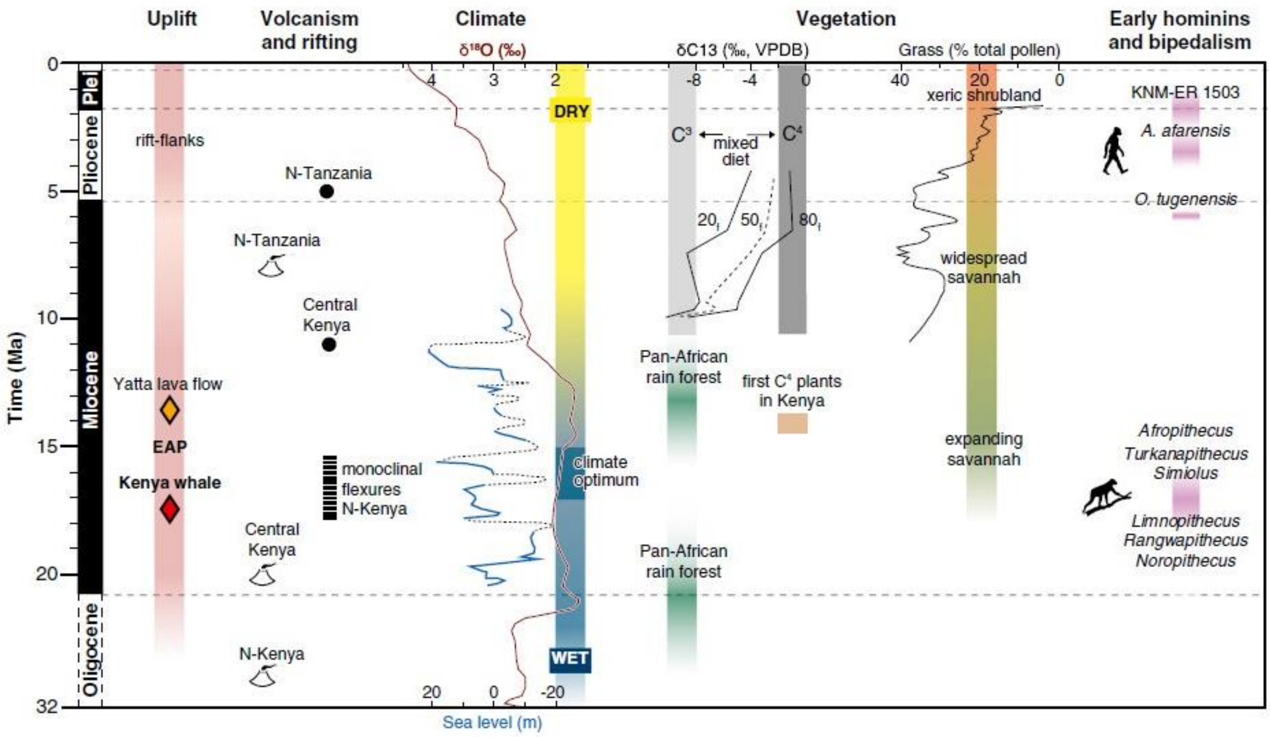


Figure 7: Cenozoic uplift chronology, climatic conditions, paleoenvironment, and early hominin evolution in East Africa. Paleoaltimetric data (diamonds) of Early to Middle Miocene onset of uplift correlate with major climatic and environmental shifts. From Wichura et al., 2015.

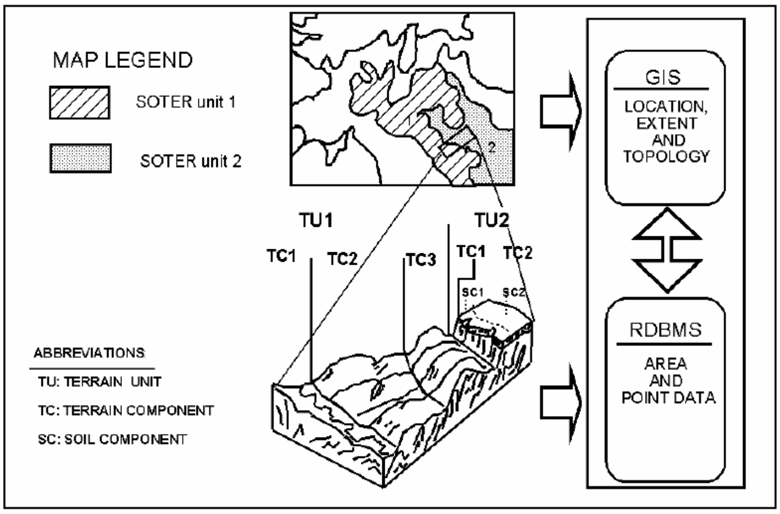


Figure 8: Relation of terrain and soil units, as used in the SOTER project (taken from Batjes, 2004). TU1 should be the Metamorphic basement landscape and TU2 the plateau formed by igneous basic rocks.

1.3 Soils

Soils vary along the agro-ecological gradient of the Embu district (Ströbel et al., 1987). In the mountainous area, humic andosols are present. The volcanic foot ridges consist mainly of nitisols (2 and 3 in fig 4), these are generally deep and permeable red clay soils. The plateaus below consist of very deep rhodic ferralsols (4). The basement system has less developed arenosols, regosols and cambisols (5,6,7). Only in the narrow valleybottoms waterlogged clay soils are present (8). In general, soil fertility declines going downslope.

Soil data is digitally available online at a 1:1.000.000 scale (see www.isric.org). A general division of soils can be observed from this data (figure 4). However, within soil units, variability can be high. Different studies present soil data from the area around Embu at a 1:100.000 scale. De Meester and Legger (1988) have produced a descriptive study of geology and soils in the northern part of the study area and Ströbel (1987) deliver soil data of the area around Embu, within the scope of a fertilizer use project. The latter only achieves a more detailed soil map in the lowest part of the study area (figure 5).

Andosol: A soil found in volcanic areas formed in volcanic tephra. Andosols are usually defined as soils containing high proportions of glass and amorphous colloidal materials, including allophane, imogolite and ferrihydrite. Because they are generally quite young, andosols typically are very fertile except in cases where phosphorus is easily fixed (this sometimes occurs in the tropics). They can usually support intensive cropping, with areas used for wet rice in Java supporting some of the densest populations in the world. Other andosol areas support crops of fruit, maize, tea, coffee or tobacco.
Nitisol: A deep, red, well-drained soil with a clay content of more than 30% and a blocky structure. These soils are found in the tropics and subtropics; there are extensive areas of them in the tropical highlands of Ethiopia, Kenya, Democratic Republic of the Congo and Cameroon. Nitisols form from fine-textured material weathered from intermediate to basic parent rock and kaolinite, halloysite and iron oxides dominate their clay mineralogy. The natural vegetation on nitisols includes tropical rain forest and savannah. Limitations frequently include low phosphorus availability and low base status, but once ameliorated, these deep, stable soils have high agricultural potential, and are often planted to crops.

Ferralsol: A red and yellow weathered soil whose colours result from an accumulation of metal oxides, particularly iron and aluminium (from which the name of the soil group is derived). They are formed on geologically old parent materials in humid tropical climates, with rainforest vegetation growing in the natural state. Because of the residual metal oxides and the leaching of mineral nutrients, they have low fertility and require additions of lime and fertilizer if they are to be used for agriculture. Tree crops such as oil palm, rubber, or coffee are suitable, but pasture is often their main agricultural use after the original forest is cleared.

Arenosols: A sandy-textured soil that lack any significant soil profile development. They exhibit only a partially formed surface horizon (uppermost layer) that is low in humus, and they are bereft of subsurface clay accumulation. Given their excessive permeability and low nutrient content, agricultural use of these soils requires careful management.

Regosols: The soil characterized by shallow, medium- to fine-textured, unconsolidated parent material that may be of alluvial origin and by the lack of a significant soil horizon (layer) formation because of dry or cold climatic conditions.

Cambisols: A soil characterized by the absence of a layer of accumulated clay, humus, soluble salts, or iron and aluminium oxides. They differ from unweathered parent material in their aggregate structure, colour, clay content, carbonate content, or other properties that give some evidence of soil-forming processes. Because of their favourable aggregate structure and high content of weatherable minerals, they usually can be exploited for agriculture subject to the limitations of terrain and climate.

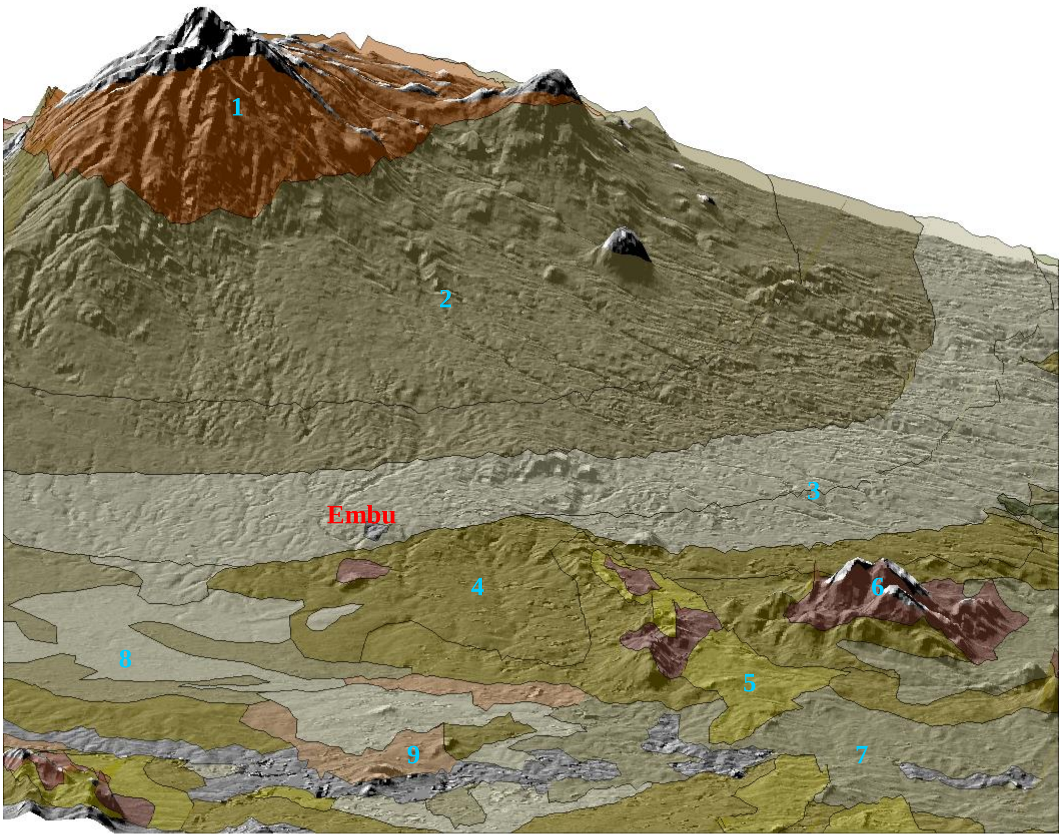


Figure 9: The eastern slopes of Mount Kenya with the 1:1000.000 soil map from www.isric.org. Draped over the freely available ASTER GDEM 30 meter digital elevation model hillshade. http://www.gdem.aster.ersdac.or.jp. ASTER GDEM is a product of METI and NASA. From top to bottom soil units are: 1) Histosols with Leptosols, 2) Nitisols with Andosols, 3) Nitisols, 4) ferralsols with Nitisols, 5) Arenosols, 6) Regosols with ferralsols, 7) Cambisols, 8) Vertisols and 9) Acrisols.

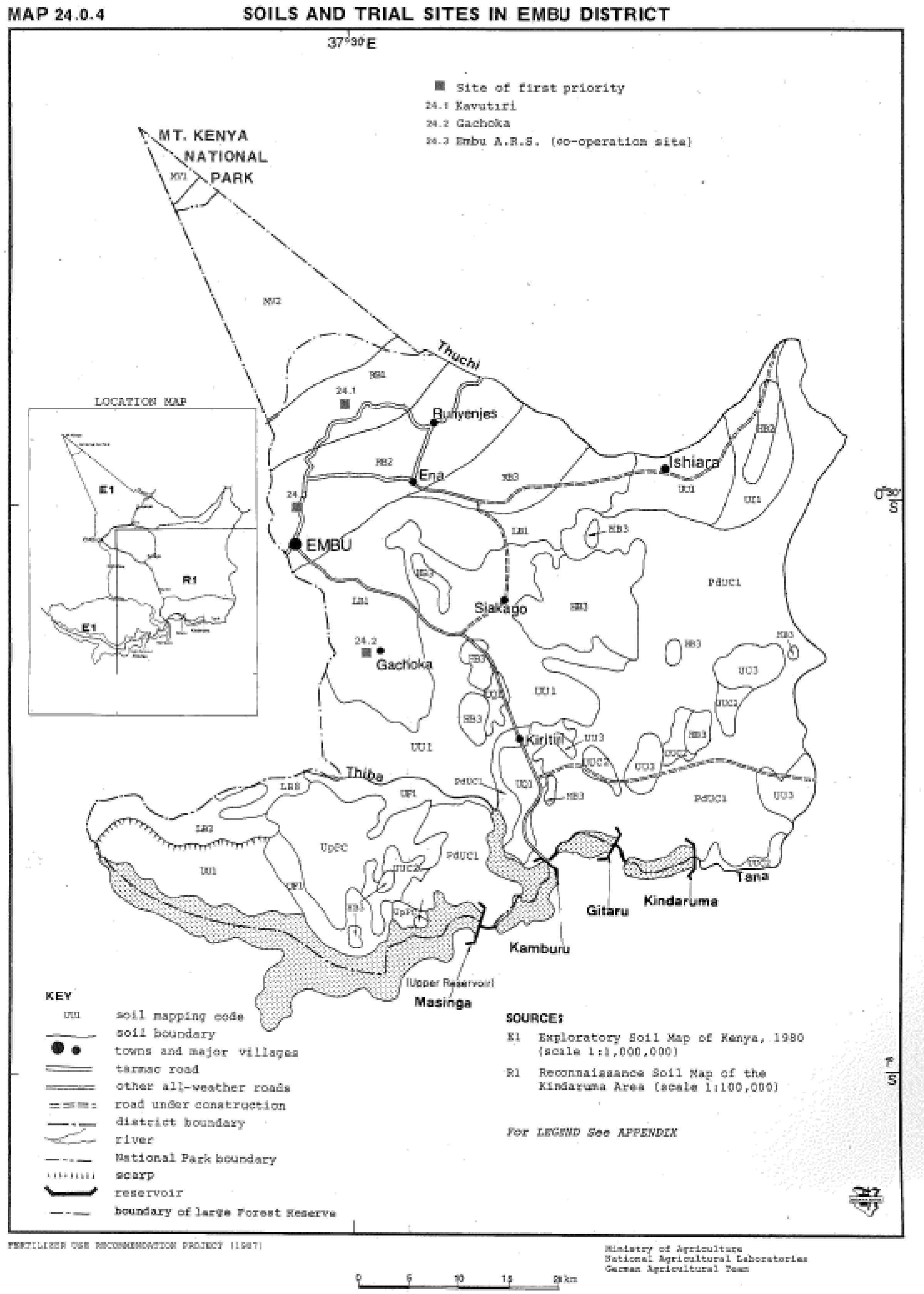


Figure 10: soil map of Embu district (Ströbel, 1987). For the legend, see reference. Note that nowadays, This area consists of two districts. The upper Embu and the lower Mbeere district.

Soils in the Embu region have inherently sufficient nutrients, but intense nutrient mining has been taking place in the Embu Region and Sub-Saharan Africa (SSA) in general since the 1980's. Stoorvogel and Smaling (1990) calculated a negative nutrient balance for SSA countries. The calculation involved the net removal of N, P and K from the soil. Soil fertility parameters in the Embu-Mbeere districts have been measured by Gachimbi (2002) for each Agro-Ecological zone (Table 1). The pH goes from acid to neutral and P, N and SOC are present in higher quantities in the Upper Midlands as in the lower midlands. However, Stoorvogel (2000) points out that variation of nutrient concentrations between farms within the same zone is extremely high and even between different units within one farm variation is high.

Table 1: Variation of pH, Hp, N, P, K, Soil Organic Carbon (SOC) and sum of cations across AEZs. Source: Gachimbu et al., 2002.

Zone No	AEZ	pH (me)	Hp	Ca (me%)	Mg (me%)	K (me%)	Ca +K + Mg	P (Olsen) (ppm)	SOC (%)	N (%)
1	TA	4.0	4.5	0.3	0.2	0.2	0.7	6.0	6.6	0.6
2	LH1	4.7	2.5	2.0	0.6	0.5	3.1	16.5	3.2	0.4
3	UM1	4.4	2.4	1.2	0.4	0.3	1.9	10.1	2.3	0.3
4	UM2+3+4	5.6	0.6	6.0	2.4	0.6	9.0	11.5	1.6	0.2
5	LM3	6.2	0.2	4.6	1.4	0.4	6.4	4.3	1.0	0.1
6	LM4	6.1	0.0	5.4	2.4	0.2	8.0	0.8	0.7	0.1
7	LM5	6.9	0.0	6.2	-	0.2	-	6.0	0.7	0.1

1.4 Hydrology

The fieldwork area is located in the upper Tana basin (figure 6). Annual and monthly discharge of this basin is shown in figures 7 and 8. The Thiba and Mutonga catchments drain the Study area into the Tana river at the southeast (figure 9) (Nyangbok and Ongweny, 1979).

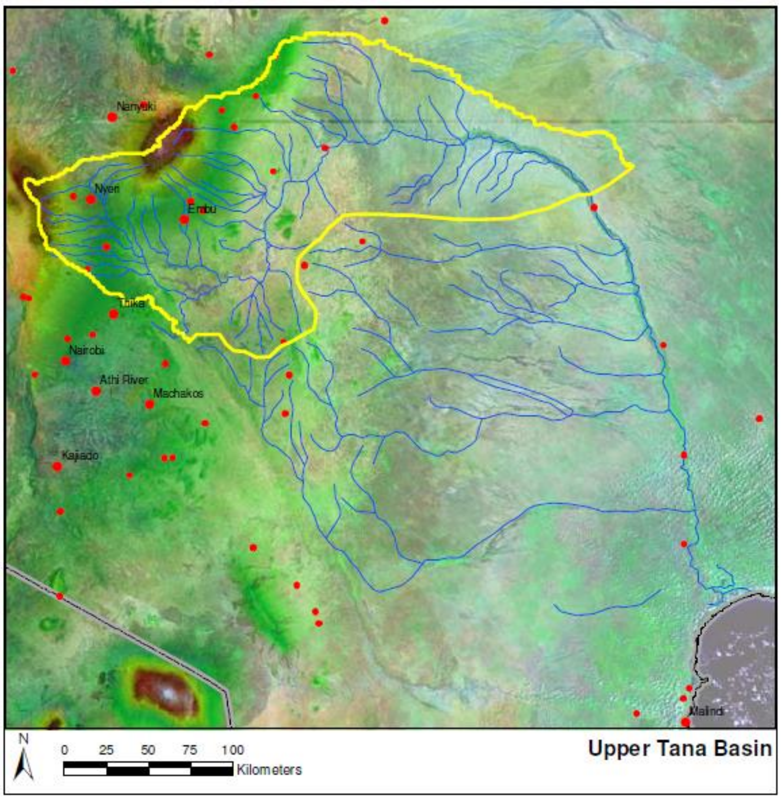


Figure 11: The upper Tana basin (Droogers et al., 2006).

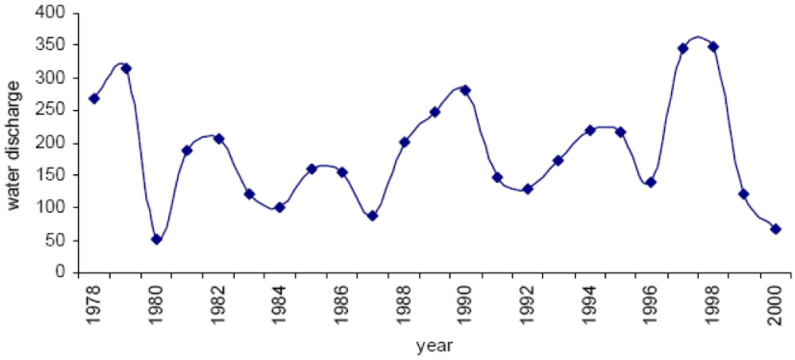


Figure 12: Upper Tana 1978 – 2000 (m^3s^{-1}). Taken from Droogers et al. (2006).

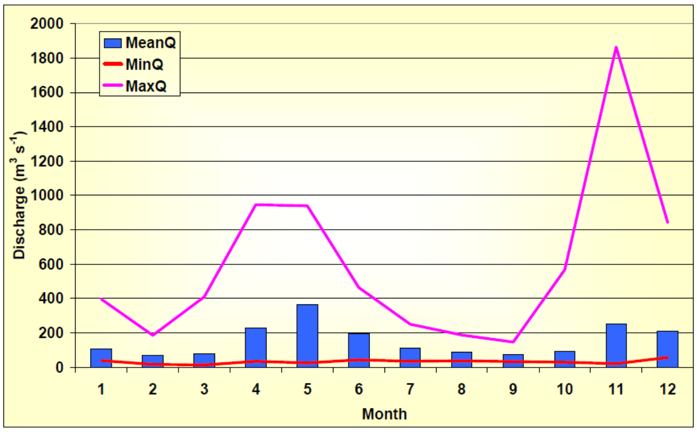


Figure 13: Discharge of the Tana at Garissa, 1934 – 1975. Taken from Droogers et al. (2006).

The tributaries of the Tana system originate in the well watered zones of high elevation covering parts of the Aberdares and Mt. Kenya with a rainfall of more than 1800 mm (figure 9). Because of the vegetative cover and the nature of the soils, erosion rates are low in spite of the steep slopes. Moving away from the steep slopes within the country lying between 1200 m and 1800 m with a rainfall of 1800 mm there is extensive cultivation forming one of the main sources of sediment being transported to the Kamburu reservoir. Within an area of 1000 m the rainfall continues to decrease markedly to less than 700 mm in places. These are areas underlain by the Precambrian rocks and characterised by intensive grazing and weathering. (Nyangbok and Ongweny, 1979).

The main erosive agent in the area is rainfall. Although total rainfall is higher going upslope, the intensity and thus erosivity of separate events is bigger in the lower dry area. The erodibility of the soils also differs. The Nitisols in the high volcanic area are less susceptible to erosion than the less developed soils in the lower western part. In general erosion hazards are biggest on steep slopes everywhere and in the basement system area. Extreme rainfall events in the late 90's have caused landslides in landslide – prone areas (Ngecu and Mathu, 1999). Vegetation and management practises positively influence soil conservation.

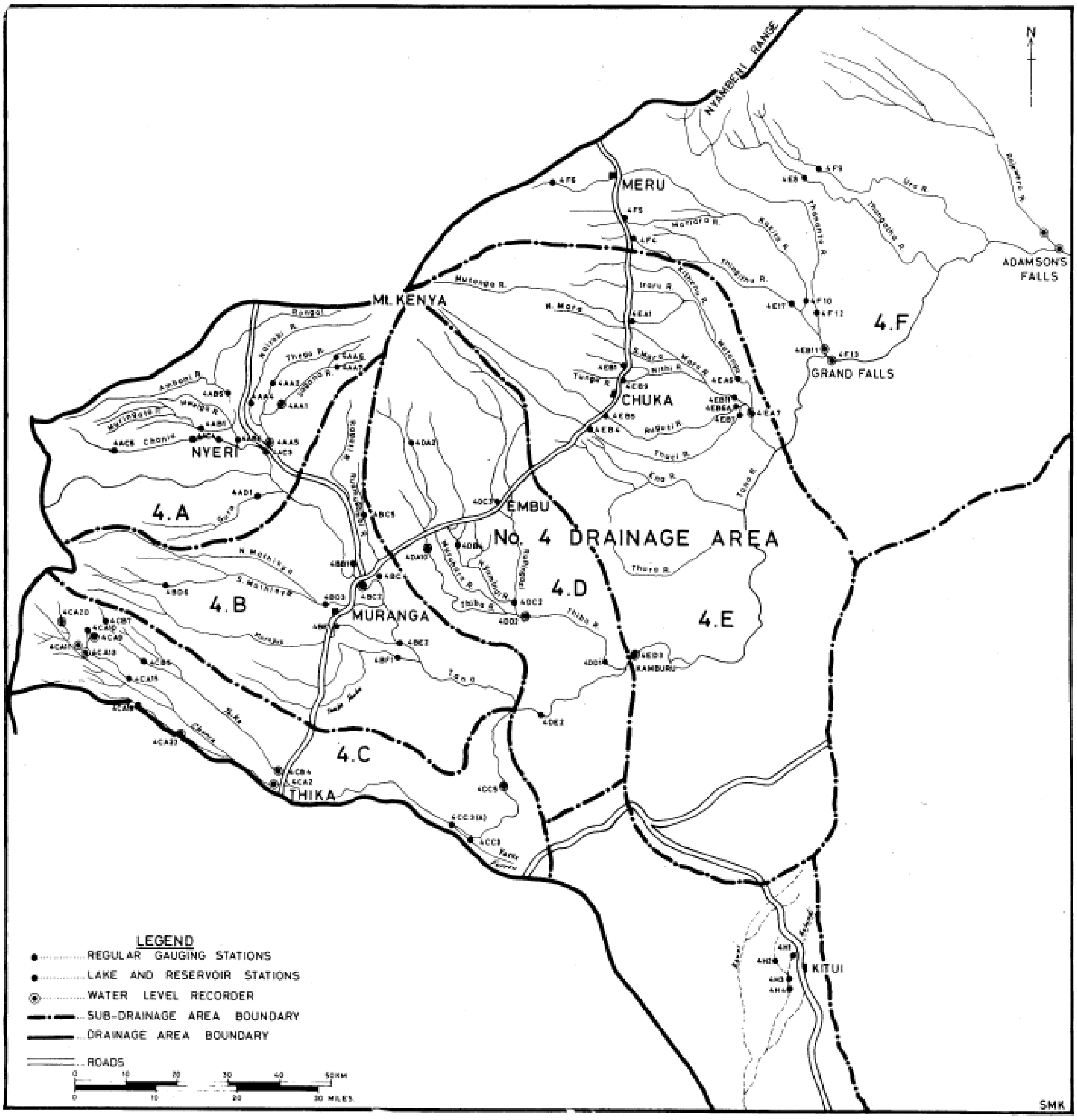


Figure 14: Drainage basins along the slopes of Mount Kenya (Nyangbok and Ongweny, 1979).

1.5 Climate

1.5.1 Past climate change

Based on six ice-cores from Kilimanjaro, Thompson et al. (2002) reconstruct palaeo-climate for eastern equatorial Africa for the last ~11.7 ka (kilo-annum = 1000 yr). Warmer and wetter conditions prevailed during the African Humid Period (~11 to 4 ka), when lake levels in the area were also high. After ~4 ka, African lake levels dropped as conditions became cooler and drier. Three abrupt climate changes are recorded in the ice records: at ~8.3, ~5.2 and ~4 ka. The first was probably a brief but strong drying period in the region. The second (~5.2 ka) is an abrupt cooling and drying event. The third climate event (~4 ka) was a ~300-year-long drought event ('The First Dark Age") with extremely dry conditions. This drought event has been considered instrumental in the collapse of a number of civilizations. Ice cover on Kilimanjaro has varied throughout the Holocene.

Karlén et al. (1999) studied lake sediments from glacier-front lakes on Mt. Kenya. Six major periods of glacier advance are recorded at ~5700, 4500-3900, 3500-3300, 3200-

2300, 1300-1200 and 600-400 cal. years BP. Many of the advances seem to coincide with periods of low precipitation and low temperature. Climate fluctuations found on Mt. Kenya are summarized in Fig. 10.

1.5.2 Short-term climate history

Nicholson (2000) analyse the nature of rainfall variability over Africa on time scale of decades to millennia. Although for the entire continent, this gives insight in the variability of rainfall (see Fig.11 and 12).

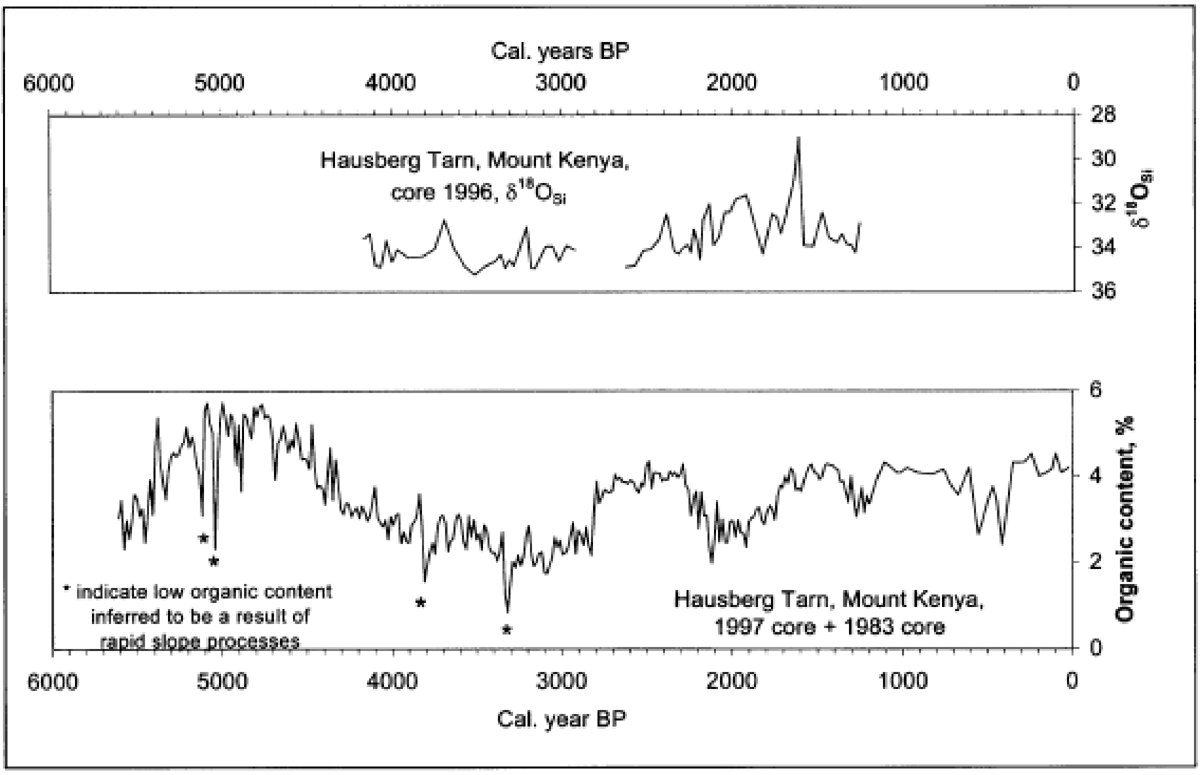


Figure 9. Organic carbon content of the sediments from Hausberg Tarn, Mount Kenya 1997. The upper 43 cm record is based on weight loss at ignition obtained on the 1983 core. The upper panel shows variations in $\delta^{18}O_{Si}$ of biogenic opal (20). $\delta^{18}O_{Si}$ reflect variations in short-term water discharge from the glaciers and long term variations in lake water temperature while. Organic carbon content reflects variations in rock flour influx from Josef and Cesar Glaciers. The main phases of glacier activity linked to climatic variations are numbered 1–15:

1. **Glacier in advanced state before 5700 cal. years BP.**
2. **Glacier retreat 5400–4500 cal. years BP.**
3. **Glacier advance 4500–3850 cal. years BP.**
4. **Warming climate, glacier retreat 3850–3600 cal. years BP.**
5. **Cooling climate, slightly lagging glacier advance 3600–3300 cal. years BP.**
6. **Warming climate, glacier retreat, around 3200 cal. years BP.**
7. **Fluctuating, relatively cool climate; glaciers were relatively large and eroding substrate, 3150–2800 cal. years BP.**
8. **Dry, cold climate; the thin wet-based glaciers become cold-based. Erosion of substrate discontinued at 2800 cal. years BP.**
9. **Cold climate, cold-based glaciers 2800–2500 cal. years BP.**
10. **Warming climate but the cold-based glaciers remain frozen to the bedrock; temperature peak 2400 cal. years BP.**
11. **Warming climate; the glaciers become wet-based and release rock flour 2250–2100 cal. years BP.**
12. **Fluctuating, warming climate; glaciers diminish in size 2100–1550 cal. years BP.**
13. **Cooling climate, renewed glacier advance 1550–1200 cal. years BP.**
14. **Glacier retreat 1200–1100 cal. years BP.**
15. **Glacier advances around 600 and 400 cal. years BP. The record for this period is less detailed.**

Figure 15: Data on Mt. Kenya climate fluctuations for the last ~6 ka. From: Karlén et al., 1999.

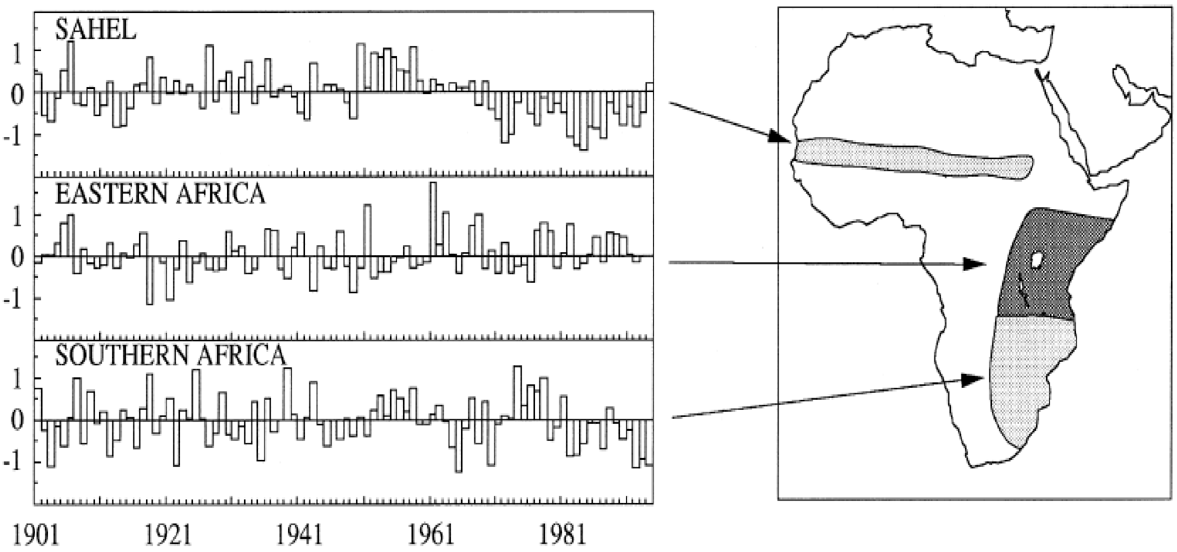


Figure 16: Rainfall fluctuations in the Sahel, eastern Africa and southern Africa from 1901 to 1994, expressed as regionally averaged standardized departure. Regions represented are shown in the small map. Source: Nicholson, 2000.

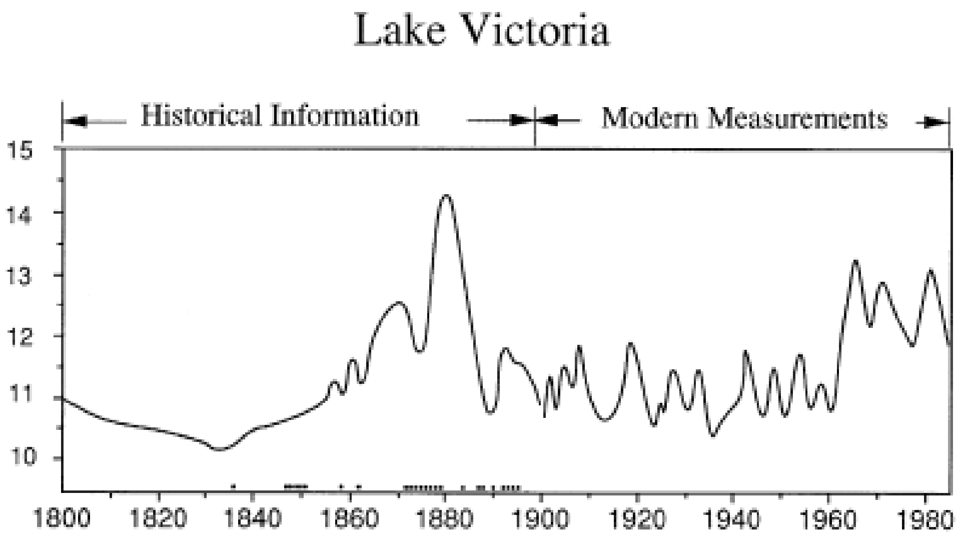


Figure 17: Fluctuations of Lake Victoria since 1800, based on documentary evidence in earlier years and actual measurements as of 1896. Source: Nicholson, 2000.

Hastenrath (2001) describes the variations of East African climate during the past two centuries. The evidence on the climatic history of East Africa over the past two centuries comprises historical accounts of lake levels, observations and analyses of glacier variations, wind and current observations in the Indian Ocean, as well as rain gauge measurements. East Africa experiences its rainy seasons in boreal spring and autumn, centred around April–May and October–November; the spring rains being more abundant and the autumn rains more variable. A drastic climatic dislocation took place during the last two decades of the l9th century, manifest in a drop of lake levels and onset of glacier recession. The decades immediately preceding 1880 featured high lake stands and extensive glaciation, as compared to the 20th century.

Odingo (1979) gives data from rainfall gauges in and near Embu town, from which spatial differences can be deduced (Table 2). Variability of rainfall can be seen in Table 3.

Table 2: From: Odingo, 1979.

Month	Mean monthly rainfall (mm)	S.D. for each month (mm)	C.V. %
January	21.9	28.5	130
February	20.7	28.2	136
March	108.4	69.8	64
April	217.0	95.9	44
May	69.6	59.6	86
June	4.7	9.2	196
July	3.3	6.4	194
August	4.0	6.4	160
September	7.3	17.5	240
October	79.2	72.4	91
November	292.9	141.5	48
December	78.4	94.9	121
Mean annual	907.4		

1.5.3 Present Climate

There are two main rainy seasons, the 'long rainy season' from March to May and a 'short rainy season' from October to November (Odingo, 1979). These are separated by a long dry season in the middle of the year running from June to October. Each season coincides with the passage of the Inter-Tropical Convergence Zone (ITCZ).

For Embu district, rainfall and evapotranspiration are shown in Fig 13:

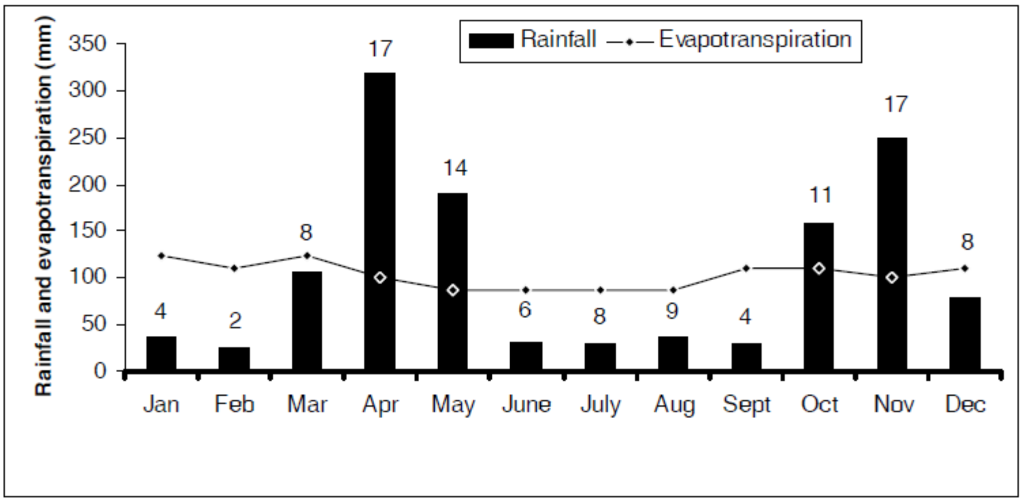


Figure 18: Long-term (25 yrs) mean monthly rainfall, evapotranspiration and number of rain-days (shown on top of the rainfall bars) for Gikuuri catchment, Embu, Kenya (Data from Embu meteorological station, No. 63720). Source: Okoba, 2005.

Mean annual rainfall is about 1289 mm and daily temperatures are between 15 °C (mean minimum) and 27 °C (mean maximum). Rainfall is often of high intensity resulting in severe soil erosion events at the onset of the rainy season.

Table 6. Rainfall stations in the Kamburu Area until 1971 (Anon., 1973).

Station	Ref. No.	Lat.	Long.	Alt. (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Length of record (years)
Embu Prov. Agr. Training Centre	90.37050	0°31'S	37°16'E	1490	23.1	24.8	91.4	301.5	222.6	28.4	42.0	43.8	43.4	149.9	206.6	60.3	1237.8	28
Siakago	90.37132	0°34'S	37°38'E	1460	175.3	0.0	160.2	487.5	69.9	4.6	0.0	11.1	0.0	8.9	241.0	42.8	1201.3	3[1)]
Machanga	90.37104	0°45'S	37°40'E	1220	35.0	25.1	101.5	160.6	84.5	6.4	2.6	3.5	23.5	85.3	212.9	89.1	830.0	13
Tebere Camp	90.37110	0°37'S	37°23'E	1220	31.6	30.4	87.2	259.9	164.0	12.8	16.0	24.4	17.0	116.2	207.1	54.5	1021.1	15
Kiambere Market	90.37135	0°42'S	37°47'E	1190	48.3	30.2	133.3	171.1	58.8	12.5	0.0	3.6	6.4	60.7	265.5	61.9	852.3	6
Mwea Exp. Station	90.37112	0°41'S	37°20'E	1160	41.2	36.0	81.5	217.9	143.0	10.2	12.2	11.8	12.0	84.1	205.3	51.6	906.8	11
Kiritiri Chief's Camp	90.37039	0°42'S	37°40'E	1140	21.0	21.4	121.5	218.2	66.4	3.9	1.7	4.7	7.4	76.5	211.2	93.7	847.6	30
Kindaruma Dam Site	90.37146	0°48'S	37°48'E	790	21.9	24.2	113.6	136.5	36.8	3.0	0.4	4.2	8.1	51.8	213.3	21.7	635.5	5
Kindaruma Fisheries	90.37176				89.4	13.3	13.9	172.9	6.3	2.5	0.3	0.0	10.7	0.4	202.2	25.3	537.2	3[1)]

[1)] 1973–75

Table 3: Monthly rainfall data from Embu Kiritiri Chief's Camp: ref. no. (90.37039) over 37 years (1938-1956; 1958-1975). Data from East African Meteorological Department. Source: Odingo (1979).

1.6 Ecology

Mount Kenya, rising to 5199 m.a.s.l., is a major water-tower that serves lowland inhabitant up to the Indian Ocean. The lower, south-eastern slopes are the wettest as the predominant weather system comes from the Indian Ocean. This leads to very dense montane forest on these slopes. High on the mountain most of the precipitation falls as snow, but the most important water source is frost. It was protected as a national park in 1949 and in 1978 its summit and the Park became a Biosphere Reserve (BR) and a World Heritage Site in 1999. Its biome is a typically mixed mountain and highland ecosystem with a rich altitudinal plant zonation (Ojany, 2004). The core zone of the BR comprises Mount Kenya National Park, consisting of Upper Montane and Afroalpine wilderness (Ojany, 2004). The buffer zone, established in 1932, comprises the Mount Kenya National Reserve, with forests of rich biological diversity (both in terms of ecosystems and species). The transition zone corresponds to an area occupied by local communities who live in proximity to the buffer zone and naturally interact intimately with this zone. this zone is under intense cultivation of both subsistence and cash crops – maize, beans, coffee, tea and so on. This is now a truly anthropogenic landscape with little remaining of the original indigenous forest vegetation; 80% of the land surface has been altered (Jaetzold and Schmidt, 1983).

1.6.1 The Biome

The Mount Kenya biome is a typically mixed mountain and highland ecosystem with a rich altitudinal zonation (Ojany, 2004). There are eight distinct vegetation bands, zones from the base to the summit:

1. Lowlands surrounding the mountain (savanna)

The area surrounding the mountain is around 1,000 m in height. It has a very hot and dry climate and the vegetation is mainly grassland and thorny scrub (Allan 1981). Many types of grasses grow here, and the trees and bushes in this area are used by the local people in a variety of ways.

2. Cultivated zone

The lower slopes of the mountain below 1,800 m have a huge potential for cultivation and are intensively farmed. Most of the area that is now cultivated around Mount Kenya used to be forest. During the deforestation to provide land for crops and grazing some trees were left standing. Sacred and useful trees were often standing, and other trees that were more frequently retained were those that grow well alongside food crops as well as species that provide shade for grazing animals. Fig trees are considered sacred by the Kikuyu, so can frequently be seen standing on their lands (Castro 1995).
Besides the retained native trees, plantations of exotic trees can also be found, such as those of pine, eucalyptus and cypress (Castro 1995)

Prior to European colonization, the people who lived around the mountain grew crops such as millet, sorghum and yams. However, since the start of the colonial period and increased options of travel (reducing the dependence of own produce), new species have been introduced and a large proportion of the agriculture around Mount Kenya is now for cash crops such as tea, coffee, beans, maize, bananas, potatoes, rice, citrus fruits, mangoes and vegetables (Castro 1995). In the higher regions of the cultivated zone and the lower range of the next to mention Montane zone (1,800 - 2,500 m) there is sub-montane forest, which is exploited by the local people. There are many forest-based industries, such as sawmills, furniture and construction, based around these slopes. (Gichuki 1999, Benuzzi 2005).

3. Montane forest

The lower limit of the forest is between 2,000 and 2,500 m (Allan 1981). Here again, there are differences in the vegetation on different aspects of the mountain.

4. Bamboo zone

The bamboo zone is found in the middle of the forest zone. It is entirely natural, and not the result of deforestation (Allan 1981). Bamboo is very dependent on rainfall. For this reason, it is very sparse in the north, and in some places absent entirely. Bamboo suppresses other vegetation, but there are scattered trees in this zone, including juniper, podocarpus, and witch-hazel, plus varieties of flowers, ferns and mosses (Mount Kenya Map and Guide 2007).

5. Timberline forest

The timberline forest is usually found between 3,000 and 3,500 metres, although it extends to lower altitudes on the drier slopes (Allan 1981) Smaller trees dominate in the timberline forest, and the characteristic trees are African rosewood (*Hagenia abyssinica*) and Giant St John's Wort (*Hypericum*). The common flowers are red-hot poker (Kniphofia thomsonii), giant forest lobelia (*Lobelia bambuseti*) and violets (*Viola* spp.) (Allan 1881, Mount Kenya Map and Guide 2007)

6. Heathland and chaparral

This zone is found between 3,200 and 3,800 metres where heathland is found in the wetter areas and chaparral in the drier area. Most of the plants in these areas are shrubs with small leaves. In the heathland Erica is dominant. In chaparral the plants are often shrubbier and more aromatic, such as African sage (*Artemisia afra*) and sugarbush (*Protea kilimanjaro*) (Allan 1981).

7. Afro-alpine zone

The Afro-alpine zone starts at about 3,800 metres and is characterised by thin dry air and a huge temperature fluctuation. Vegetation becomes sparser at this altitude but some plants have evolved to live without roots, such as lichens and moss-balls. Similarly, tufted species are adapted to high fluctuations in temperature and consequently the dominant plant in the Afro-alpine zone on Mount Kenya is the tussock grass *Festuca pilgeri* (Young and Peacock 1992).

8. The nival zone

The nival zone is the area above most vegetation. On Mount Kenya this area is usually above 4,500 metres. There are still scattered giant groundsels, *Helichrysum* and *Lobelia*, as well as a few other plant species.

1.6.2 Conservation issues

Mount Kenya has an exceptional biodiversity value, owing to the succession of different bio-ecological zones at close range (Gichuki 1999). Many species are endemic or highly characteristic of Mount Kenya such as the lobelias, the senecios and the rock hyrax.

With the advent of commercial agriculture an enormous pressure on the natural surrounding became evident. For instance, in 1909 elephants were abundant in Mt. Kenya while by 1924 the sighting of elephants was becoming less common and elephants had become adapted to forest life seeking refuge from man (Percival, 1924). By 1950s, elephant crop raiding had become a long-standing problem warranting the building of moats to protect farms and shooting on control. Similar trends were observed for other wildlife species depending on level of conflict with human activities (Maitima *et al.*, 2004). Currently, there are an estimated 2000 elephants in the forest. Their migration to the adjoining Aberdare Forest has declined as their corridors have been blocked by human settlements. (Ojany, 2008)

The human pressure on land and it's natural surroundings on the slopes of Mount Kenya has increased the CITES red-list species for the region, including leopard, Eastern bongo, giant forest hog, black rhino, African elephant (Appendix II of CITES listing) and black-fronted duiker. Besides the mammalian wildlife, Mount Kenya is an important bird area.

About 53 of Kenya’s 67 African Highland biome species, at least 35 forest species and 6 of the 8 species from Kenyan Mountains Endemic Bird Area reportedly occur on Mount Kenya (Bennun and Njoroge, 1999)

1.6.3 Human wildlife interaction

The main forms of human-wildlife conflict are competition for land and grazing resources and damage caused by problem animals such as elephants, buffaloes and baboons. Damage includes human injury or death and damage to crops, forest plantation and infrastructures such as fences. Conflict between human and wildlife has increased because of increases in animal and human population. The conflicts are exacerbated during the dry season when food and grazing resources are scarce. With the expansion of human settlements, areas previously used by wildlife have been converted for agriculture and livestock production. The pressure is highest in densely populated mountain areas. The perception of the affected people is that the government is protecting wildlife more than it is protecting them. (Gichuki, 1999).

Vertebrate species that due to their behavioural plasticity are able to adapt to the changing ecology and survive in agricultural systems often come into direct competition with humans and are persecuted as pests whereas those that do not are forced into small marginal patches (Maitima *et al.*, 2004).

1.6.4 The Mount Kenya National Park and Biopshere Reserve

Because of the previous mentioned developments and threats with respect to biodiversity decline, an area around the centre of the mountain is designated a National Park (since 1949). In 1978 its summit and the Park became a Biosphere Reserve (BR) and listed as a UNESCO World Heritage Site in 1999. The park receives over 15,000 visitors per year. The total area of the park is 142,020 hectares (ha) including:

- Mt. Kenya National Park 71,500 ha
- Mt. Kenya Natural Forest 70,520 ha

The core zone of the BR comprises Mount Kenya National Park, consisting of Upper Montane and Afroalpine wilderness (Ojany, 2004). The buffer zone, established in 1932, comprises the Mount Kenya National Reserve, with forests of rich biological diversity (both in terms of ecosystems and species). The transition zone corresponds to an area occupied by local communities who live in proximity to the buffer zone and naturally interact intimately with this zone. this zone is under intense cultivation of both subsistence and cash crops – maize, beans, coffee, tea and so on. This is now a truly anthropogenic landscape with little remaining of the original indigenous forest vegetation; 80% of the land surface has been altered (Jaetzold and Schmidt, 1983).

The management plan of Mount Kenya National Park has three main goals:

1) to preserve the afro-alpine ecosystem
2) to preserve the traditions and values of a high mountain wilderness for enjoyment by visitors
3) to preserve Mount Kenya's contribution of Kenya's environmental quality.

2. Human dimension

2.1 Demographics

General demographics

The population pyramid of Kenya is typical of countries with falling infant mortality rate (Figure 17). More recent data suggests a similar fertility rate with person 0-14 years 42.6 % of the population (male 7,454,765; female 7,322,130) persons 15-64 years 55.1 % of the population (male 9,631,488; female 9,508,068) and persons 65 years and over 2.3 % (male 359,354; female 432,012) (2006 est.). Birth rates are high 39.72 births/1,000 population (2006 est.) and death rates are moderate 14.02 deaths/1,000 in comparison to worldwide figures (2006 est.). Net Migration is listed as non-existent but according to the UNHCR, by the end of 2005 Kenya was host to 233,778 refugees from neighbouring countries, including Somalia 53,627, Sudan 67,556, Ethiopia 12,595 (2006 est.)

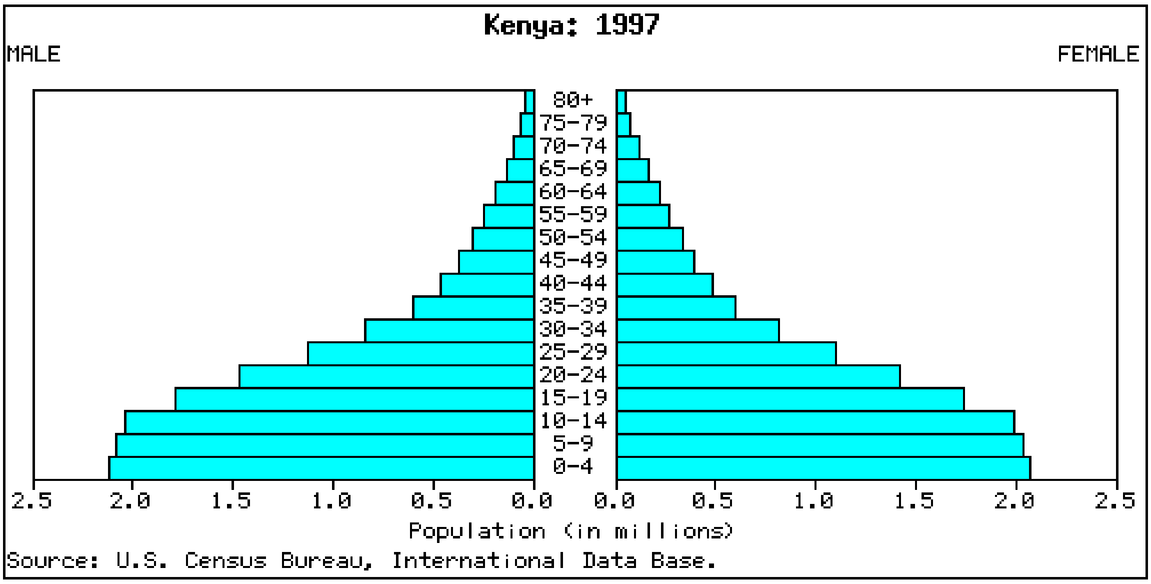


Figure 19: Population pyramid of Kenya

Demographics in Embu

Population density increased in Embu in the 1950 due to declining infant mortality rates, however highland areas are more densely populated than low land areas (Olsen et al., 2004). In highland areas population densities increased from 272 people/km2 in 1969 to 702 people in 1999. In low land zone densities went from 339 to 662 in the same period. Table 4 illustrates the trend in comparison to other provinces and map 1 shows the concentration of population on the slopes of Mount Kenya where agricultural productivity is higher. Mbeere a relatively less populated areas south of Embu has also undergone population density growth. In 1969 the sub-district had 31 people/km2. In 1999 it had 81 people/km2 (Kenya, 1970, 2000)

Table 4: Population Embu and surrounding districts (1969 -1999)

District	Area (km2)	1969	1979	1999	Number of household	
					1979	1999
Nyeri	3284	360 845	486 477	661 156	98 222	168 786
Embu	2714	178 912	263 173	278 196	50 241	121 168
Meru	9922	596 506	830 179	1 409 373	150 662	286 913
Isiolo	25 605	30 135	43 478	100 861	10 097	22 583
Kirinyaga	1437	216 988	291 431	457 105	53 729	114 439
Laikipia	9718	66 506	134 524	322 187	30 281	78 175

Source Ojay, 2008

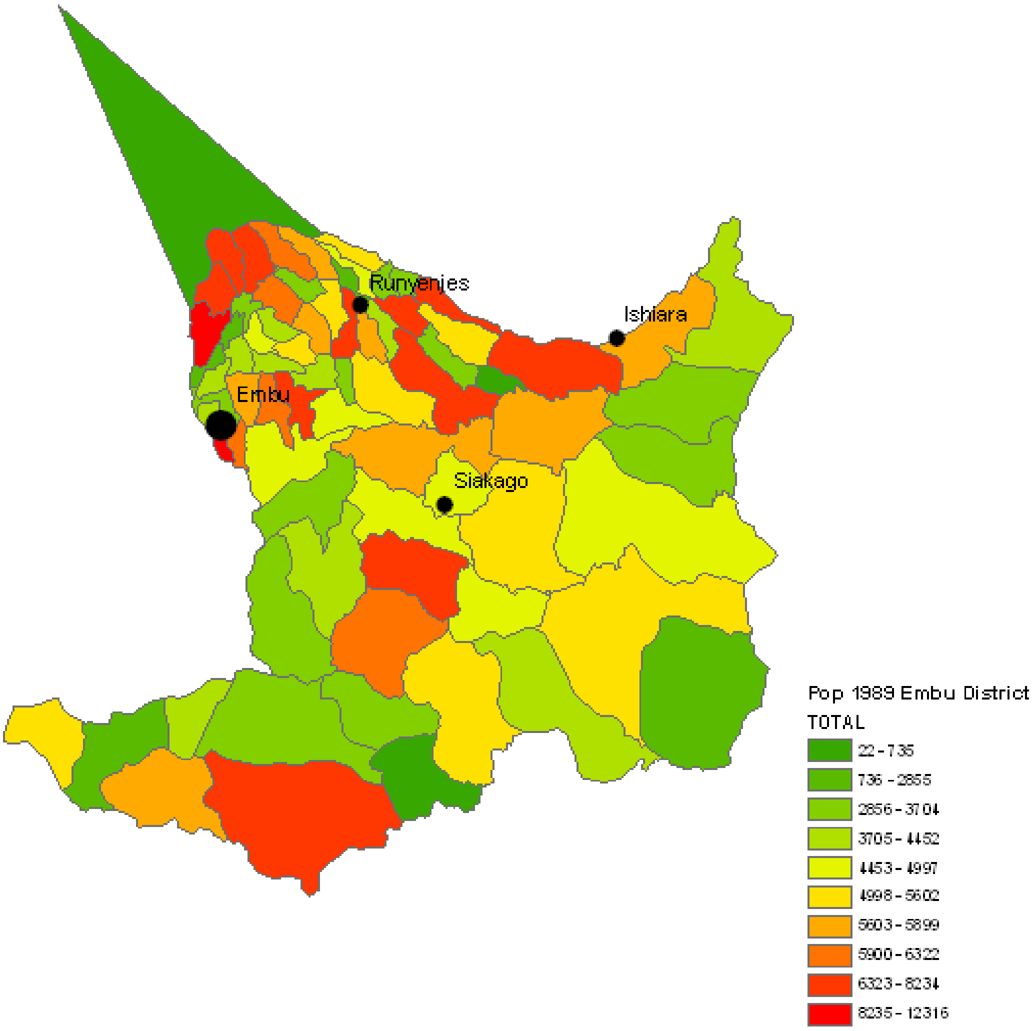


Figure 20: Population distribution the district of Embu 1989

2.1.1 Education Level

Estimates of the Kenyan literacy rate range between 75 and 85 percent. However, female rate about 10 points lower than males. The education system is plagued by non-enrollment and low completion rates. The first eight years of schooling is compulsory and is free beginning at age six. After primary education there is four years of secondary school, and four years of university education. The language of instruction from the secondary stage onward is English. Primary enrollment since 2002 has included about 75 percent of children. This enrollment rate remains below the nearly 100 percent rate, a previous marked attained in 1980s before mandatory user-fees which were implemented with donor pressure. The primary school completion rate in 2002 was less than one-half. Primary school enrollment has increased under the Kibaki government, which immediately fulfilled its campaign pledge to abolish user charges and special fees. The government now offers universal free primary education, a change from earlier cost-sharing arrangements between the government and parents. Secondary school enrollment in 2002 included only about 23 percent of the relevant age-group and remains low. Greater government expenditures on education (8 percent of gdp and 30 percent of current government spending in 2004) may reverse the declining trend in educational standards but also increase the fiscal deficit.
Kenya has five public universities and about twice that many private institutions of higher education. Since the 1980s, there has been a tremendous expansion in universities in response to high demand. The public universities are the University of Nairobi (founded

in 1956); Kenyatta University (1972), in Nairobi; the Jomo Kenyatta University of Agriculture and Technology (1981), near Nairobi; Egerton University (1939), near Nakuru; and Moi University (1984), outside Eldoret. The government also provides opportunities for higher education through several polytechnic institutes and several dozen teacher-training colleges.

Education in Embu

In general farmers tend to have low education levels with the majority of household heads having little education above primary level. Land shortage in Embu has been a motivating factor for investment in children's education. Educated individuals migrate to region, looking for work outside of the agricultural sector. Of those households with adult sons, 66 percent have at least one son who has migrated away (Olsen, 2002). Despite school fees being outlawed, they remain an expense for higher education (primary school became free in 2004, but fees are still charged for other levels). Fees paid range from US$ 8.86 (K Sh 700) to about US $ 20.25 (K Sh 1600) and these are levied on a family rather than an individual student (Mukudi, 2004).

2.1.2 Religion

About three-quarters of Kenyans profess some form of Christianity, although fewer are affiliated with a church. About 40 to 45 percent of Kenyans are Protestant, while 30 percent are Roman Catholic. Estimates for the percentage of the population that adheres to indigenous beliefs and to Islam vary widely, ranging from 10 to 25 percent for the former and 7 to 20 percent for Muslims. One percent are Hindus and Sikhs. The population includes very few professed atheists.

Table 5: Percentage of religious beliefs for Kenya

Protestant	45 %
Roman Catholic	33 %
Indigenous beliefs	10 %,
Muslim	10 %
Bahá'í Faith	1% approx.
Buddhism	2 %

2.1.3 Ethnicity and languages

People of African descent make up about 97 percent of the population; they are divided into about 40 ethnic groups belonging to three linguistic families including the Bantu, Cushitic, and Nilotic. Bantu-speaking Kenyans comprise three groups the western (Luhya), highlands (including the Kikuyu and the Kamba), and coastal (Mijikenda) Bantu. The major groups of Nilotic speakers are the river–lake (Luo), highlands (Kalenjin), and plains or eastern (Masai). The Cushitic-speaking groups include the Oromo and Somali. The Kikuyu, who make up 22 percent of the population, constitute Kenya's largest ethnic group. The next largest groups are the Luhya (14 percent), Luo (13 percent), Kalenjin (12 percent), and Kamba (11 percent). Additional groups include the Kisii (6 percent), Meru (6 percent), and other African (15 percent). Small numbers of people of Indian, Pakistani, and European descent live in the interior, and there are some Arabs along the coast. The official languages of Kenya are Swahili and English; many indigenous languages from the three language families also are spoken.

Table 6: Ethnic groups of Kenya

Majority Groups	*Minority Groups*	*Other non-Kenyan*
- Kikuyu (Agĩkũyũ) 20.78 % - Luhya 14.38 % - Luo 12.38 % - Kalenjin 15.46 % - Kamba 11.42 % - Kisii 6.15 % - Ameru (Meru) 5.07 % - Maasai 1.76 % - Turkana 1.52 % - Embu 1.20 % - Taita 0.95 % - Swahili 0.60 % - Samburu 0.50 %	- Aweer - Bajuni - Bukusu - Dahalo - Isukha - Kore - Kuria - Maragoli - Marama - Miji Kenda - Ogiek - Orma - Pokomo - Rendille - Sengwer - Suba - Tachoni - Taveta - Watha - Yiaku	- Oromos - Somalis - Gujaratis, Baluchs, Punjabis and Goans from India, - Britons - Hadhrami and Omani Arabs - Italians

There are two major ethnic groups in the Embu district the Embu and the Mbeere. Both the Embu share many of the cultural and social practice of the Kikuyu and other related peoples of central Kenya. The Embu and Mbeere people are close relatives and speak the same Bantu language. The Embu live mostly on the higher slope of Mount Kenya or the highlands and produce cash crops and are subsistent farmers who also rear cows, goats and sheep. Formally social status was judged the number of wives and children a man had.

The Mbeere people, who number less than 100,000, inhabit the lower south-east slopes of Mount Kenya, stretching down from Embu and what was once the edge of the forest - to the relatively dry bush country and winding course of the Tana River. The higher land in the north-west is suitable for coffee cultivation, while the lower zones are classed as semi-arid and are not dominated by any cash crop, though cotton is grown in some areas. The principal subsistence crops are maize and bulrush millet. Administratively Mbeere forms the lower part of Embu

2.1.4 Health

In general health is poor in Kenya and health indicators reflect this. Infant mortality rate are high at 59.26 deaths/1,000 live births (2006 est.). Malnourished population is also high 32% in worldwide comparisons. Life expectancy at birth is low at 48.93 years; male: 49.78 years, female: 48.07 years (2006 est.).

Tropical diseases, especially malaria, and tuberculosis have long been a public health problem in Kenya. In recent years HIV – AIDS has become a severe problem. Estimates of the incidence of infection differ widely. The UNDP claimed in 2006 that more than 16 percent of adults in Kenya are HIV-infected, whereas UNAIDS cites a much lower figure of 6.7 percent. In 2004 the Kenyan Ministry of Health announced that HIV/AIDS had surpassed malaria and tuberculosis as the leading disease killer in the country. Thanks largely to AIDS, life expectancy in Kenya has dropped by about a decade. Since 1984 more than 1.5 million Kenyans have died because of HIV/AIDS. More than 3 million Kenyans are HIV positive. The prevalence rate for women is nearly twice that for men. The rate of orphanhood stands at about 11 percent.

The 2006 human development index ranked Kenya 152nd out of 177 citing poor performance in infant mortality. Estimates of the infant mortality rate range from 57 to 74 deaths/1,000 live births. The maternal mortality ratio is also among the highest in the world, thanks in part to female genital cutting, illegal since 2001 for girls under 16.

Apart from major disease killers, Kenya has a serious problem with accidental death, specifically by motor vehicles. Kenya has the highest rate of road accidents in the world, with 510 fatal accidents per 100,000 vehicles (2004 estimate). In February 2004, in an attempt to improve Kenya's appalling record, the government obliged the owners of the country's 25,000 *matatus* (minibuses), the backbone of public transportation, to install new safety equipment on their vehicles.

Kenya's health infrastructure suffers from urban-rural and regional imbalances, lack of investment, and a personnel shortage, with, for example, one doctor for 10,150 people (as of 2000).

Over the past several decades, Kenya has seen declining income per head and growing disparities of income and wealth. Various estimates between 2000 and 2006 stated that the top decile of the population enjoyed 37 to 42 percent of income, while the lowest decile had only 1 to 2 percent. The number of people living below the poverty line (as defined in Kenya) is estimated to have increased from 11.3 million (48.4 percent of the population) in 1990 to 17.1 million (55.4 percent of the population) in 2001.

Health in Embu
Data about health in Embu is not readily available. Outpatient morbidity (diseases) for the district hospital suggest high rate of malaria. The map below indicates the prevalence of Malaria spread for the region suggesting that Embu is a low risk area. In Embu there are high instances of female circumcision (CBS, 1998)

Table 7: Percentage of diseases treated at Embu District hospital

Outpatient morbidity data for Embu District Hospital*

Year / %	2000	%	2001	%	2002	%
Disease type						
Malaria	87898	29.1	128682	31.9	139985	29.4
Respiritory. system	68392	23	93742	23.2	97500	20.5
Intestinal worms	25385	8.4	33796	8.4	36268	7.6
Skin infection	22850	6	25972	6.4	29468	6.2
Pneumonia	14771	5	16515	4.1	18576	4
Diarrhea	10525	3.5	12714	3.2	10913	2.3
Rheumatism	5882	2	9756	2.4	10873	2.3
Eye infection	5333	2	7274	2	12762	2.7
Urinary tract infections	4513	1.5	5644	1.4	6681	1.4
Total new cases	271181		371668		437781	

***Source: Embu district Health Annual report.**

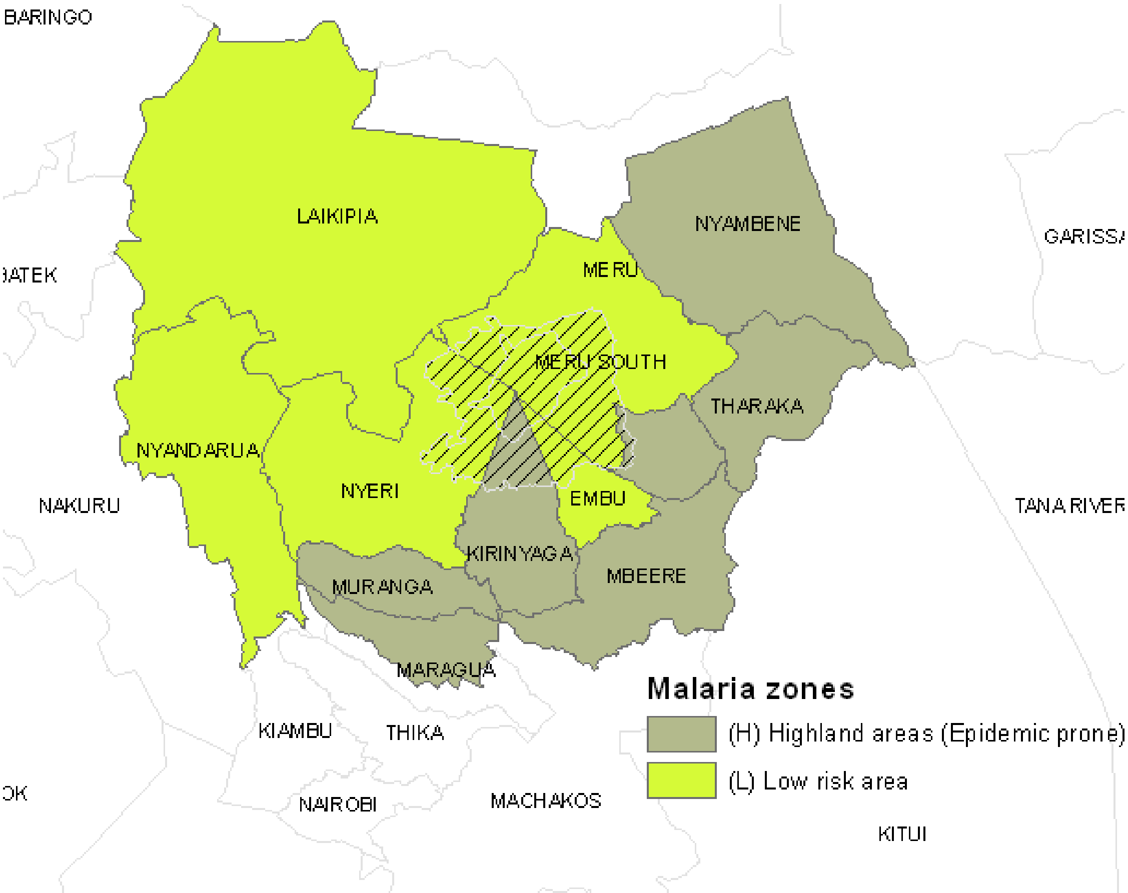


Figure 21: Estimation of the Malaria risk in Embu and surrounding districts

2.2 Economics

Kenya's economy is market-based, with some state-owned infrastructure enterprises, and maintains a liberalized external trade system. The economy's heavy dependence on rain-fed agriculture and the tourism sector means income earning vulnerability. The agricultural sector employs nearly 75 percent of the country's 37 million people. Half of the all agriculture is subsistence production (CPK, 2007).

Kenya's gross domestic product (GDP) growth rate while continuously increasing has declined proportionally annually from 6.5 percent to 1.5 percent per year during the 1990s.Hower, recently the county has experienced growth 5 percent per year since 2004. Declining economic performance in tandem with rapid population growth has meant reduced income per head, increased poverty, and worsening unemployment. Between the 1970s and 2000, the number of Kenyans classified as poor grew from 29 percent to about 57 percent.

Kenya's economic performance is hampered by a number of interacting factors. Heavy dependence on a limited amount of agricultural exports, population growth that does not correspond to economic growth, prolonged drought, deteriorating infrastructure, and extreme disparities of wealth that have limited upward mobility have all been factors. Poor governance and corruption have also had a negative impact on growth, making it expensive to do business in Kenya. Kenya ranks among the world's half-dozen most corrupt countries. The 23 % of Kenyans living on less than US$1 per day, pay some 16 bribes a month—two in every three encounters with public officials. Another large drag on Kenya's economy is the burden of HIV/AIDS.

Prospects have brightened somewhat under the Kibaki government, whose policy aims include budgetary reforms and debt restraint. The economy has seen a broad-based expansion, led by strong performance in tourism and telecommunications, and acceptable post-drought results in agriculture, especially the vital tea sector. Nevertheless, risks to continuing robust growth remain, including weak infrastructure, drought, political instability in the run-up to the December 2007 elections, and diminution of financial flows from donors because of ongoing corruption allegations (Okwi et al, 2007).

KEY ECONOMIC RATIOS and LONG-TERM TRENDS

	1987	1997	2006	2007
GDP *(US$ billions)*	8.0	13.0	22.8	29.5
Gross capital formation/GDP	24.3	15.2	21.8	19.5
Exports of goods and services/GDP	21.3	22.8	25.1	22.8
Gross domestic savings/GDP	19.2	9.0	9.5	9.1
Gross national savings/GDP	16.6	11.7	12.5	11.4
Current account balance/GDP	-7.7	-3.5	-6.8	-10.3
Interest payments/GDP	2.8	1.4	0.3	..
Total debt/GDP	72.6	49.6	28.7	..
Total debt service/exports	40.4	21.8	7.1	..
Present value of debt/GDP	..	..	21.9	..
Present value of debt/exports	..	..	81.7	..

	1987-97	1997-07	2006	2007	2007-11
(average annual growth)					
GDP	2.4	3.5	6.1	6.9	6.1
GDP per capita	-0.8	0.8	3.3	4.1	5.5
Exports of goods and services	5.3	6.5	9.2	12.5	6.6

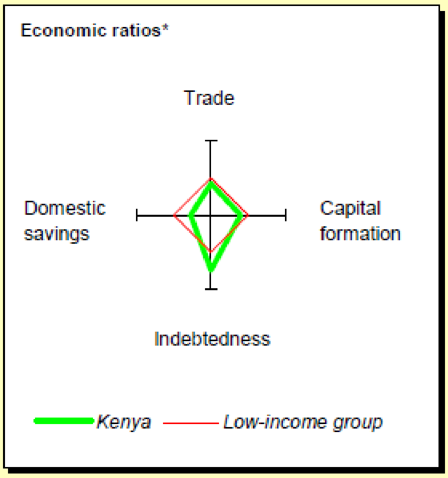


Figure 22: Source: World Bank website

Economics in Embu
Embu is an agricultural dominated centre and district head of the eastern province. The eastern province's primary sector is agriculture (Okwi et al, 2007). In the 1950's the farming system was characterized by extensive grazing of grassland with small areas of shifting cultivation. Since independence, coffee and, more recently, tea plantation have been established. These are located on the slopes of Mount Kenya due to favourable climactic conditions. There are a number of livelihood strategies in the areas including – part-time subsistence farmers small holders/unskilled workers a small but poor segment of the population; mixed smallholders a larger segment with greater time spent farming; staple producers, a largest group that has on average 1.6 acres of land; off-farm, skilled employment; and finally diversified/commercial which include cash crops and fodder production (Brown et al, 2006). The farming system is not mechanised and requires high labour inputs and this has caused increases in population density. However, population growth is larger than the provision of land and there is a land scarcity issue in the region. Some farmers are able to rent land in low land areas but out-migration is also prevalent.

Table 8: Key figures for the country of Kenya

Data Profile				
	2000	2005	2007	2008
World view				
Population, total (millions)	6,078.27	6,462.05	6,614.40	6,692.03
Population growth (annual %)	1.3	1.2	1.2	1.2
Surface area (sq. km) (thousands)	133,945.2	133,945.8	133,945.8	134,095.4
Poverty headcount ratio at national poverty line (% of population)	..	..	..	..
GNI, Atlas method (current US$) (billions)	32,000.30	45,525.91	52,850.78	57,637.51
GNI per capita, Atlas method (current US$)	5,265	7,045	7,990	8,613

Data Profile				
	2000	2005	2007	2008
GNI, PPP (current international $) (billions)	41,851.85	56,416.08	65,815.30	69,308.96
GNI per capita, PPP (current international $)	6,885	8,730	9,950	10,357
People				
Income share held by lowest 20%	..	..	..	..
Life expectancy at birth, total (years)	67	68	69	..
Fertility rate, total (births per woman)	2.7	2.5	2.5	..
Adolescent fertility rate (births per 1,000 women ages 15-19)	59	53	51	..
Contraceptive prevalence (% of women ages 15-49)	..	..	60	..
Births attended by skilled health staff (% of total)	..	..	65	..
Mortality rate, under-5 (per 1,000)	83	71	68	..
Malnutrition prevalence, weight for age (% of children under 5)	..	..	23	..
Immunization, measles (% of children ages 12-23 months)	73	79	82	..
Primary completion rate, total (% of relevant age group)	82	86	87	..
Ratio of girls to boys in primary and secondary education (%)	92	95	95	..
Prevalence of HIV, total (% of population ages 15-49)	0.9	0.9	0.8	..
Environment				
Forest area (sq. km) (thousands)	39,792.3	39,426.5	..	..
Agricultural land (% of land area)	38.1	38.2	..	..
Renewable internal freshwater resources per capita (cubic meters)	..	..	6,620	..
Improved water source (% of population with access)	82	..	..	..
Improved sanitation facilities, urban (% of urban population with access)	77	..	..	..
Energy use (kg of oil equivalent per capita)	1,668	1,795	..	..
CO2 emissions (metric tons per capita)	4.1	4.5	..	..
Electric power consumption (kWh per capita)	2,390	2,674	..	..

Data Profile				
	2000	2005	2007	2008
Economy				
GDP (current US$) (billions)	32,001.93	45,232.14	54,891.06	60,587.02
GDP growth (annual %)	4.1	3.5	3.8	2.0
Inflation, GDP deflator (annual %)	4.7	4.9	5.4	8.1
Agriculture, value added (% of GDP)	4	3	..	..
Industry, value added (% of GDP)	29	28	..	..
Services, etc., value added (% of GDP)	67	69	..	..
Exports of goods and services (% of GDP)	24	27	..	..
Imports of goods and services (% of GDP)	25	27	..	..
Gross capital formation (% of GDP)	22	22	..	..
Revenue, excluding grants (% of GDP)	..	25.2	26.7	..
Cash surplus/deficit (% of GDP)	..	-1.7	-0.8	..
States and markets				
Time required to start a business (days)	..	50	43	38
Market capitalization of listed companies (% of GDP)	102.3	97.5	120.7	59.4
Military expenditure (% of GDP)	2.3	2.5	2.4	2.4
Mobile cellular subscriptions (per 100 people)	12	34	51	60
Internet users (per 100 people)	6.7	16.2	21.3	..
Roads, paved (% of total roads)	36	..	..	..
High-technology exports (% of manufactured exports)	23	21	18	..
Global links				
Merchandise trade (% of GDP)	41.1	47.0	50.8	52.8
Net barter terms of trade (2000 = 100)	..	..	..	..
External debt stocks, total (DOD, current US$) (millions)	..	..	..	..
Total debt service (% of exports of goods, services and income)	..	..	..	..
Net migration (thousands)	..	..	..	..
Workers' remittances and compensation of employees, received (current US$) (millions)	131,519	270,504	380,050	433,087
Foreign direct investment, net inflows (BoP, current US$) (millions)	1,518,702	1,116,371	2,139,338	..
Official development assistance and official aid (current US$) (millions)	57,878	107,671	105,056	..
Source: World Development Indicators database, April 2009				

2.3 Social system

Culture

The Embu people (or a man, their common ancestor, Mũembu) believe they are created by Ngai (God) when he created the rest of mankind and that the man Mũembu and his close kinsmen migrated into Embu country from the Meru area (Saberwal, 1967). Lambert (1950, not available) mentioned a tradition for the Embu, 'which derives themselves from an ancestor of that name and his sister, whom he took to wife'. Linguistically and culturally the Embu are closely related to the Kikuyu, the Cuka, the Meru and other Bantu people living around Mt Kenya (Middleton *et al.*, 1965, not available).

The mountain is regarded with great respect by local communities and many people still consider it a repository of spiritual power (Kiteme *et al.*, 2008).

Cattle, and to a lesser degree sheep and goats, had great social significance. To possess animals meant wealth, and the wealth of a household was generally measured in 'cattle units". The animals were given away as dowries or slaughtered on special social or religious occasions (De Meestester *et al.*, 1988).

Clans

A clan was thought to be a land-owning corporate group, which disciplined its members and acted collectively in relation to non-members, however, abundant case material showed conclusively that, beyond the homestead, descent groups were only weakly corporate with no institutionalised intra-clan roles (Saberwal, 1967).
Memberships in a genealogical generation were institutionalised. All the sons entered a generation-set following their fathers' set in elaborate, co-ordinated, tribe-wide succession ceremonies.

The land was essentially communal property but was entrusted to individual clans, families or households for long periods of time (De Meestester *et al.*, 1988). Power has shifted from clans to families, changing gender roles, wealth differences, high value placed on education, on sacred forests (Maitima *et al.*, 2004). The population places great importance on land ownership, accordingly the resulting land fragmentation is such that many households own no more than 0.4 ha (Ojany, 2004).

Gender roles

The "traditional" family, with a wife and husband who live and work on their own farm and whose sons expect to work on their parents land, is no longer the experience of many households. Indeed, only 60% of the surveyed households in Embu and 50% in Mbeere (the lower areas) meet this definition. In Mbeere especially, wives manage many farms because the husbands are absent. This frequent and long-term absence of husbands has affected the activities that women do on the farm, and their role in the society: *"Before, jobs were divided. Men did the heavy job of digging. Now it is more equal, women see that they can do all jobs so they dig, and do other things. There is little difference in jobs. Women feed the animals, too."* (Olson, 2004)

Households thus have varying compositions that include widows as heads, female headed with the husband away, and husband present but working elsewhere (Olson, 2004).
Currently there are no new areas for the increased population to cultivate or settle. The trend is migrations to the lower zones where land is still available and to urban centres to do business and seek employment (Maitima *et al.*, 2004).

3. Land use

Different ecological conditions have led to different farming practices in the highland and lowland parts. The land use varies from the tea dairy farming in the upper Embu through the mid altitude coffee cultivation zones to the lowlands where cotton and annual cereal crops are the main crops (Figure 21; Maitima *et al.*, 2004). Four distinct farming systems can be divided: 1) Tea-coffee-dairy system, 2) coffee-maize-beans system, 3) cotton-maize-pigeon pea system, and 4) livestock-millet-(cotton) system.

Highland people are traditionally at home in the coffee-maize-beans system, their houses are concentrated along the road from Embu to Meru. Each household possessed grazing land in the uplands (Tea-coffee-dairy system). The land around the house was used for production of root and tuber crops, such as yam, taro, sweet potatoes and cassava, and for other crops like bananas, gourds, sugar cane and miraa. Bananas and sweet potatoes were of special importance as they composed the greater part of people's calorie intake. In the cotton-maize-pigeon pea system, the land was used for the production of small grains, pulses, and for the growing of tobacco and sweet potatoes. Agriculture in the lowlands (confined to livestock-millet-cotton system) had less sedentary character than in the highlands; shifting cultivation was common. Depending on the natural fertility of the land, fields were cropped for 2 to 7 seasons. A period of occupation was usually followed by a 10 to 20 years fallow. Animal husbandry was practiced throughout the area, however the animals were not used in land preparation. Cattle, sheep and goats grazed away from the homestead; special pastures were not prepared and manure was hardly used. De Meestester and Legger (1988, pages 148-158) have described the farming systems in more detail.

The development of urban settlements shows that they are poorly planned with roads responsible for gully erosion, which is exacerbated by the steep slopes (Ojany, 2004).

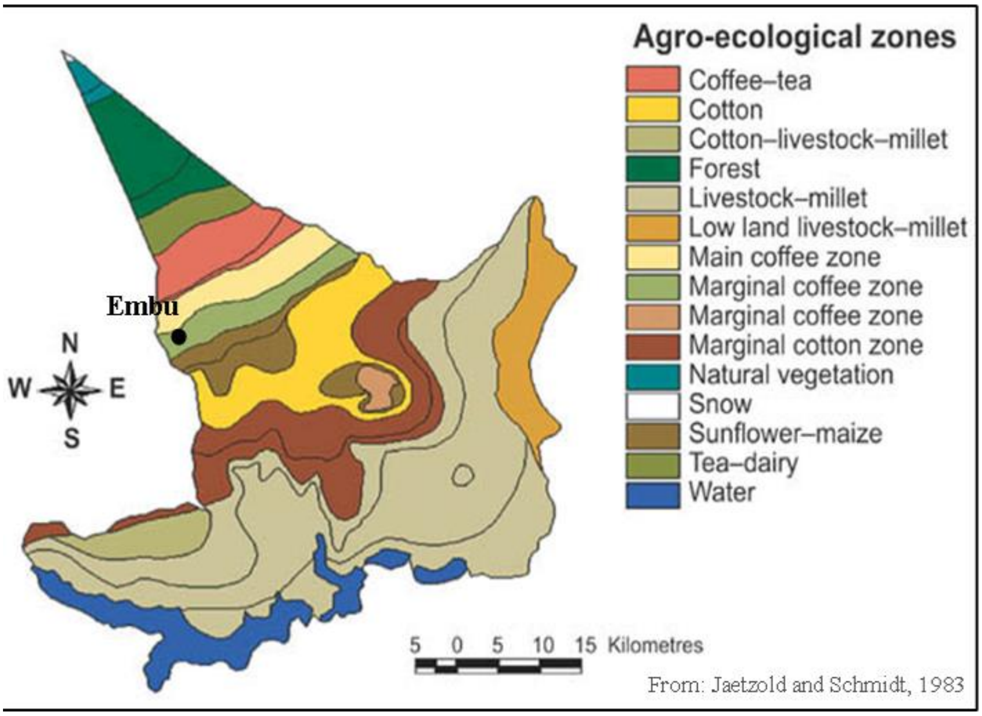


Figure 23: Agro-ecological zones of South-east Mount Kenya, including Embu region

3.1 Management

The land use in Embu Mbeere is characterised by certain specific land management activities like ploughing and weeding, use of manure and fertilizers, use of insecticides and herbicides. These different management activities have direct impact on the dynamics of vegetation due disturbance. From a management point of view, the land use could be categorised into three major types namely: livestock grazing, commercial mono-crop farming and subsistence mixed crop farming. Comparing species abundance between these systems showed that grazing systems have the highest plant diversity while cultivations of mono-crops have the lowest, as land use intensification increases, cultivation replaces natural vegetation in agro-ecosystems and the number of species decline due to the loss of native species as weeds start to invade. (Source: Maitima *et al.*, 2004)

In comparison to smallholder farms that grow subsistence mixed crops and plough by oxen, the larger commercial farms of monoculture crops are structurally simpler and biologically less diverse. The efficiency achieved by mechanisation in crop production is therefore achieved at the expense of natural vegetation (Maitima *et al.*, 2004).

The level of soil and water conservation and application of inputs increased greatly the upper agro-ecological zones, partly assisted by support or insistence of the government, but also because farmers appreciated the results. Manure was particularly appreciated because it improved the soil's condition as well as increased yields (farmers complained that chemical fertilizers eventually ruin their soil). In the 1990's before the coffee and tea prices collapsed, many of the wealthier Embu farmers were purchasing truck loads of manure brought in from the lower agro-ecological zones—ironic since the farms of Mbeere have much lower levels of fertility, and more of their fields show worsening fertility. The level of soil maintenance in terms of applying inputs is, in general, much lower in the lower agro-ecological zones than in the upper agro-ecological zones (figure 22).

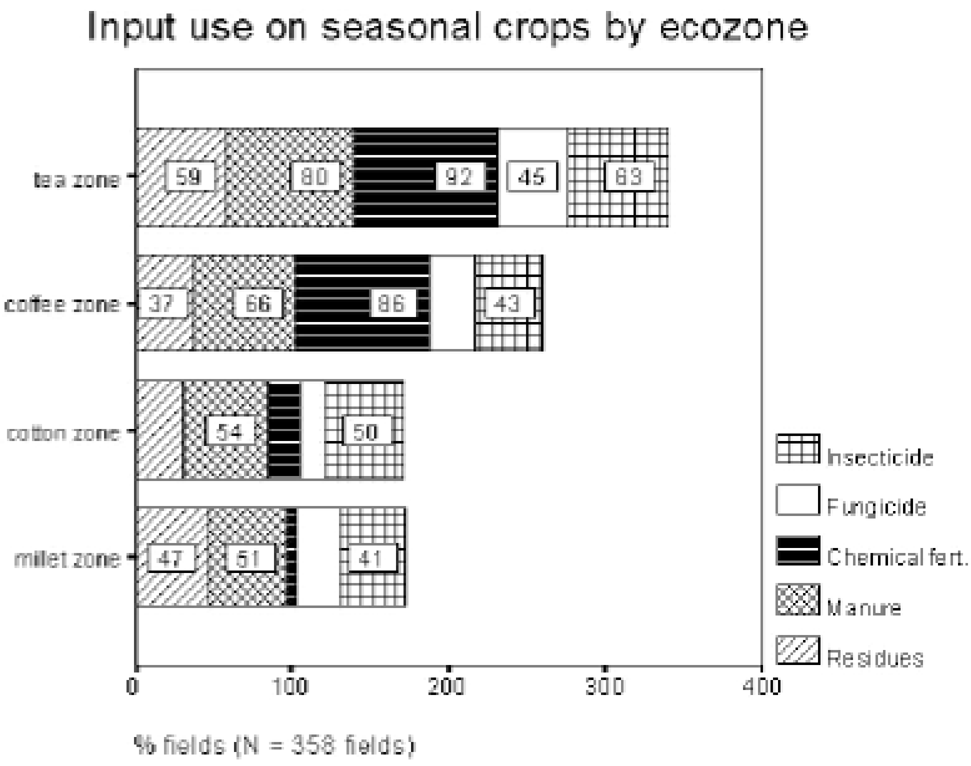


Figure 24: Percent of fields with seasonal crops where soil inputs were applied by agro-ecological zone (Olson, 2004).

Table 9: Land use change statistics, northern Embu site (Mbuyori). Source: Maitima et al., 2004.

Land use	1958		1985		1958-1985		1995		2001		1985-2001	
	Km2	%	km2	%	km2	%	km2	%	km2	%	km2	%
Forest	11.4	17.5	11.1	16.9	-0.4	-0.6	12.3	18.8	13.5	20.6	2.5	3.8
Bush	23.1	35.4	0.0	0.0	-23.1	-35.4	0.0	0.0	0.0	0.0	0.0	0.0
Shamba system	0.4	0.6	0.5	0.7	0.1	0.1	0.8	1.3	0.9	1.4	0.4	0.6
Tea Plantation	0.0	0.0	1.2	1.9	1.2	1.9	1.9	2.8	3.1	4.7	1.9	2.8
Tea/Coffee	29.8	45.6	52.6	80.2	22.7	34.6	50.1	76.5	47.7	72.9	-4.8	-7.3
Urban	0.6	0.9	0.2	0.3	-0.4	-0.6	0.4	0.6	0.3	0.4	0.1	0.1
TOTAL	65.4	100	65.5	100			65.5	100	65.5	100		

3.2 Land use change

Four important developments have taken place since 1950: 1) land consolidation and adjudication, 2) introduction of coffee, tea and some other cash crops, such as cotton and tobacco, 3) introduction of grade cattle for milk production, and 4) replacement of millet by maize as the main staple (De Meestester *et al.*, 1988). The following is a summary of land use changes in Embu Mbeere districts from 1958 to 2001. The most significant change is the change from 23% of bush cover in 1958 to the levels that are undetectable from Land Sat Satellite image of 2001. See table 9 and figure 23. Olsen (Olson, 2004) recognised several driving forces, including political, economic, demographic, social-cultural, and locational context (Box 1).

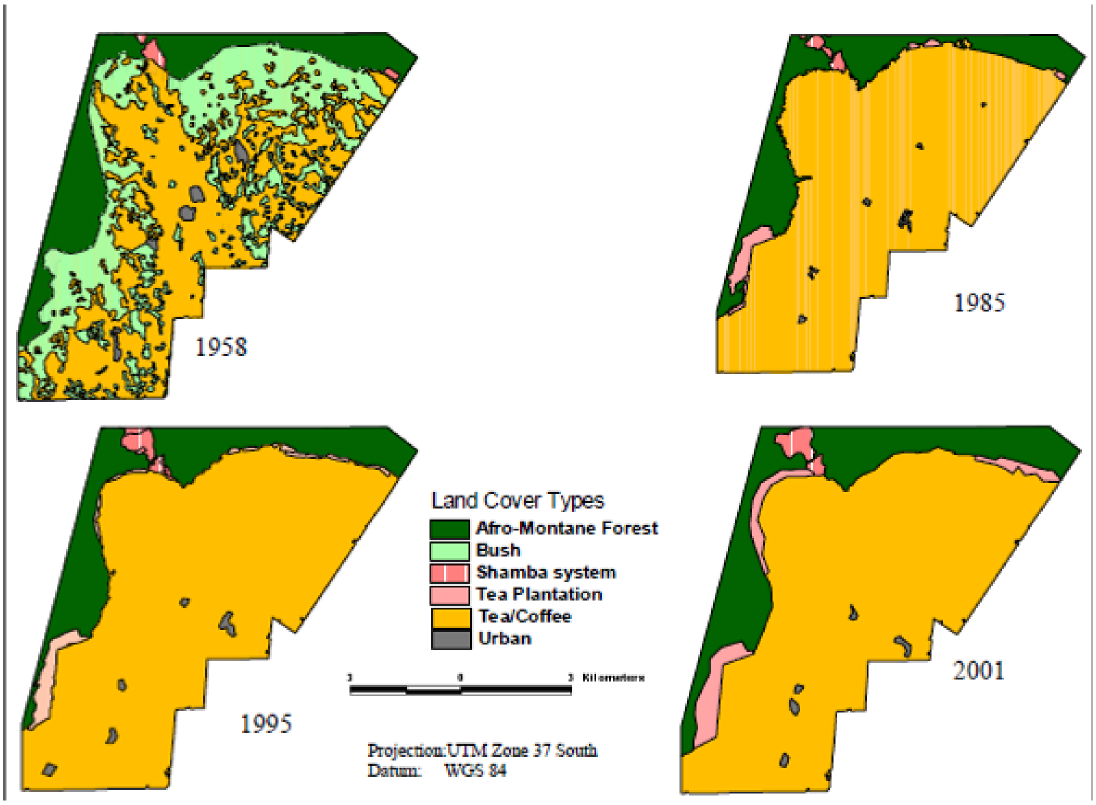


Figure 25: Land use change in northern Embu District (Mbuvori) from 1958 to 2001. Source: (Olson, 2004)

Box 1: Major driving forces of land use change (Olson, 2004).

Political:

Kenya government: land polices (adjudication, conservation), changing enforcement of regulations, elections/ stability, infrastructure investment, coffee & tea promotion, health of cooperatives/ parastatals

International: environmental organisations, structural adjustment, aid, commodity prices

Economic:

Changing relative labour and economic returns to crops vs. animals, to farm vs. non-farm

Changing markets for maize, coffee, charcoal, timber , miraa, horticulture

Availability of off-farm employment

Demographic:

Local pop. growth and low land availability→in-filling and intensification

Migration: to look for land (upper to lower zones)→extensification, to look for employment

Falling birth rates, HIV-AIDS

Social/ cultural: power from clans to families, changing gender roles, wealth differences, high value placed on education, on sacred forests

Locational context: remoteness, marginal environment, strength of national ties

3.3 Governance

3.3.1 Colonialism

Kenya's governance structures have been marked by a legacy of colonialism. This colonial legacy is one factor of contemporary institutional dysfunction. Kenya was both an Arab and Portuguese colony with inland goods flowing to maritime centres controlled by the foreigners. Later Kenya became an English colony with the Berlin conference in 1885, which carved up Africa for the European powers. The colonial powers favoured European settlers who largely colonized the fertile Kenyan highlands, in some cases taken from African owners. The English rule usurped indigenous Kenyan political interest, limited the cultivation of cash crops by Kenyans, permitted forced labour, maintained a white highland and force native Kenyans' to small reserves.

Independence

Protests by Africans about colonialism began in 1920 and peaking in the 50s lead to independence in the 60s. On December 12, 1963 Kenya gain independence but retained its commonwealth status. Kenyatta a key figure in the independence movement was elected the first president. He quickly initiated a large buy back of land from white settlers for Africans. However, much of this land went to influential Kenyans who had close ties with Kenyatta. After criticism of this policy Kenyatta backed redistribution to hundreds of thousands of African small-land holder and invested heavily in education.

Kenyatta presidency

Under Kenyatta Kenya did very well with the best economic growth on the continent, this despite droughts, two oil shocks, ethnic conflicts and border skirmishes. However, the economy was largely based upon a range of primary products, which made Kenya vulnerable to shifts in world prices. His rule also marked growing disparity in the distribution of wealth that, with much of it the hands of Kenyatta and his close associates. Poverty numbers also remained very high and even increased with population growth. Kenyatta died in 1978 and vice president Danial arap Moi succeeded him

The Moi presidency

Popular at first, Moi promised to tackle corruption, limit foreign ownership of industry, review his predecessor's land allocation policies and the wealth distribution, and abolish primary school fees. However, a deteriorating economy necessitated fiscal austerity and these measures were hardly realized. Moi began to follow in Kenyatta's autocratic footsteps. In 1982, the ruling party, KANU, amend the constitution to make Kenya officially a one-party state and KANU the sole legal party. Throughout the 80s, Moi tightened political control despite widespread corruption amongst authorities. Eventually, Western powers and international financial donor agencies cut-off financial aid and by the 1990s, suspended grants and loans, pending political and economic reforms and improvement in the records on human rights and corruption. Moi bowed to pressure from donors and opposition groups and agreed to an amendment reinstating multiparty elections. In 1992 the first multiparty elections in 26 years were held. However the ethnically fractured opposition failed to dislodge Moi and KANU from power. Moi continued to hold power for two terms until 2002 when he was force to retire as part of constitutional law. This period was marked by much of the same corruption

3.3.2 Contemporary issues

The next elections are purported to be the most free in Kenyan history but were still reported to have inconsistencies. Kibaki a former vice president to Moi was elected prime minster. He faced new challenges immediately with the drafting of a new constitution. The new constitution included controversial proposal of for example a new office of prime minister, an upper chamber of parliament, the decentralization of powers to the district level and constitutional recognition of Islamic courts. This proved unpopular and Kibakis own party splintered into sub parties and the constitution reforms were defeated. Discussions about the new constitution are continuing.

Kibaki's rule has improved Kenya in many regards including universal free primary education, anticorruption measures, checks on the judiciary and improved economic growth. International aid is now again flowing in to the country however, continued corruption has also made donor weary of providing aid. In general the country is burdened by poor infrastructure, an agricultural based economy, poverty rate exceeding 50 , endemic corruption, crime, and a heavy burden of disease including AIDS HIV. There is also growing ethnic tensions as several bombing can attest to. Finally the country has been experiencing a large drought and is now home to Somali refugees fleeing the conflict in Somalia.

3.3.3 Embu in depth

Embu forms a municipality that has seven wards (Blue Valley, Itabua, Kamiu, Kangaru, Majengo, Matakari and Njukiri). All of them belong to Manyatta Constituency, which has a total of eleven wards. The remaining four are located within Embu County Council, the rural council of Embu District.

With its high agricultural potential Embu has for a long time been the focus of national governmental programmes to increase productivity. During colonial rule Embu's land tenure system was altered in an attempt to increase yield. Traditionally clan elders made the decisions on who was to cultivate what land. This system had served the community well because it separated the crops from grazing animals, ensured sufficient land for maintaining large goat herds, and provided sufficient woodfuel and other forest products. In the cultivated areas, soil productivity was maintained by long fallow periods. However, English policy (the Swynnerton Plan of 1954) subdivided the already occupied land and by independence in1963, the adjudication plan had been fully implemented and all families lived on and cultivated only their individual plots. Clan elder aided the subdivision of land but the general feeling by Embu residents was of confinement as they could no longer shift cultivation (Olsen et al, 2004).

The colonial administration also started a terracing programme to increase agricultural yields. Chiefs enforced this tax payment. However, following independence, the enforced terracing programme ended and many people, very resentful of how they had been forced, removed them. This created problems with continuous cropping of the same fields which when combined with erosion led to rapidly declining soil fertility. To alleviate poor fertility the independent government permitted small-holders to grow the remunerative cash crops of first coffee and later tea and gave credit for farmers to purchase chemical fertilizers, pesticides and fungicides for the coffee and tea. Other effort where also made when in the 1970 terracing for coffee and tea fields became mandatory. In the 1980's the terracing program increased its reach with the Ministry of Agriculture and the Swedish International Development Agency collective effort for all fields within designated catchments (Berlekom and Larsson 1984; Admassie 1992).

National Parks

A large portion of the Embu district is located in a national park, which can be seen in the map below (map 2). Mount Kenya National Park established in 1949, protects the region surrounding Mount Kenya. In April 1978 the area was designated a UNESCO Biosphere Reserve (international protection recognition). The national park and the forest reserve, combined, became a UNESCO World Heritage Site in 1997.

The Government of Kenya cites four reasons for creating a national park around Mount Kenya as the importance of tourism for the local and national economies, to preserve an area of great scenic beauty, to conserve the biodiversity within the park, and to preserve the water catchment for the surrounding area. The prospects of economic return are high and earning from tourism are 12 percent of Kenya GDP (Akama, 1999) however, forest uses by locals are also important as a source of r fuel wood, food and building material (Emerton, 1999).

Water

The right to water has also become an issue with growing uses of the resource (Boniface et al, 2002). Increased uses by upland famers have created shortage for low land areas. Current efforts to mitigate conflicts have focused on local action and representation.

Embu forms a municipality that has seven wards (Blue Valley, Itabua, Kamiu, Kangaru, Majengo, Matakari and Njukiri). All of them belong to Manyatta Constituency, which has a total of eleven wards. The remaining four are located within Embu County Council, the rural council of Embu District.

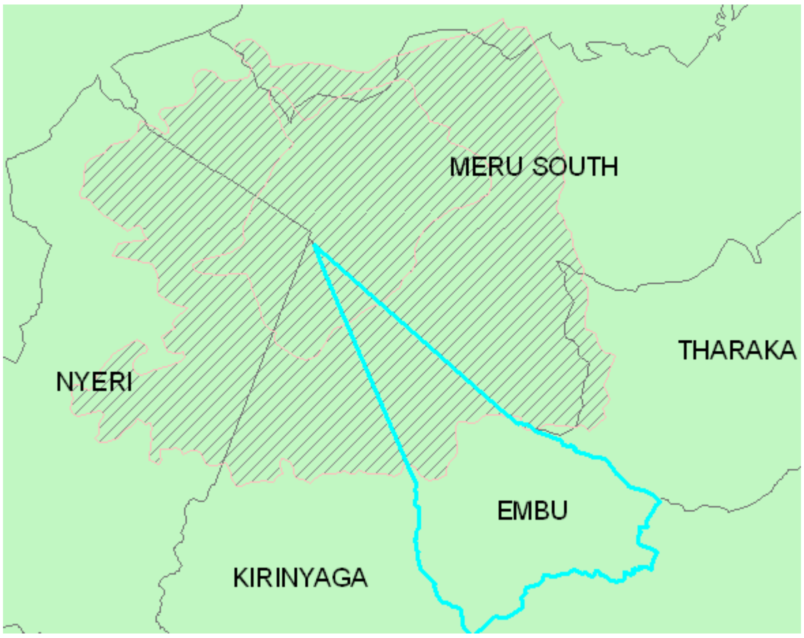


Figure 26: The boundary of Mount Kenya National Park

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