Soil Conservation Research Programme
Ethiopia

Research Report

Agroecological Belts of Ethiopia

Explanatory notes on three maps at a scale of 1:1,000,000

Hans Hurni

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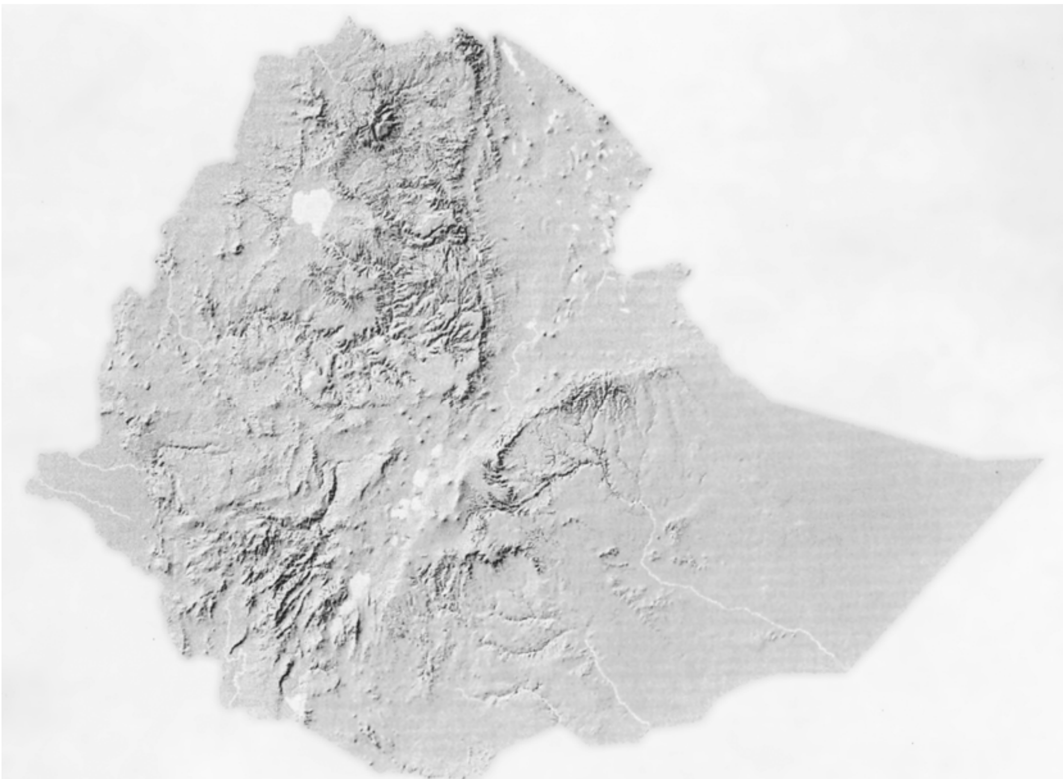

Centre for Development and Environment
University of Bern, Switzerland
in association with
The Ministry of Agriculture, Ethiopia

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Key Words: Agroecology, agroclimatology, belts, major zones, traditional altitudinal belts, GIS, digital elevation modelling, field mapping

Cover: Hill shading of Ethiopia based on a Digital Elevation Model (DEM), which was produced to apply the detailed agroecological belt mode to the Ethiopian landscape

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ABBREVIATIONS

AB	Agroecological belt
AZ	Agroecological zone
m a.s.l.	Metres above sea level
°C	Degrees Celsius
CDE	Centre for Development and Environment
DEM	Digital elevation model (a GIS tool)
EMA	Ethiopian Mapping Authority
FAO	Food and Agriculture Organisation
GIUB	Geographical Institute, University of Berne
GIS	Geographical information system
GPS	Global positioning system
LGP	Length of growing period
LUPRD	Land Use Planning and Regulatory Department
MAZ	Major agroecological zone (e.g. ABs)
MoA	Ministry of Agriculture
NRMRD	Natural Resources Management and Regulatory Department (of MoA)
SCRP	Soil Conservation Research Programme
SWC	Soil and water conservation
UNDP	United Nations Development Programme
WDLUPD	Watershed Development and Land Use Planning Department

SUMMARY

From 1987 to 1995, a collaborative project was carried out between the Centre for Development and Environment (CDE) of the Institute of Geography of the University of Berne, the Soil Conservation Research Programme (SCRP), and the Ethiopian Mapping Authority (EMA). Its aim was to produce a map of Agroecological Belts of Ethiopia, at a scale of 1:1,000,000 by presenting a sound, geo-referenced overview of 'major agroecological zones' (MAZ) of Ethiopia based on an improved 'digital elevation model' (DEM) and altitudinal zonation of traditional rainfed cropping patterns as primary denominators of the belts. The maps are a mixture of field observations, altitudinal differentiation according to temperature conditions, and a very precise, geo-referenced application of the model based on a digital elevation model for the whole country.

Methodologically, a three-step approach was employed: First, a new topographic base had to be developed at the scale of 1:1 million, derived from 1:250,000 and 1:50,000 scale maps of EMA, and supplemented with additional information on road networks and locations. This involved several years of work by a small staff and included computerised data storage in a Geographical Information System (GIS), as well as traditional cartographic skills at a high level of sophistication.

A second step was the development of an agroecological model focusing on major agroecological zones (MAZ) according to altitude and cropping patterns. The latter was basically derived from field observations whereby about 11% of the Ethiopian landscape was visited and observed by the author over a period of 20 years, from 1974-1993. In the highlands, i.e. the Weyna Dega, Dega, High Dega and Wurch zones, coverage of the observed landscape was considerably greater, amounting to 26% of these zones. Altitudinal belts were delimited according to the occurrence of major cereal crops, such as barley for the High Dega Belt; barley, wheat and pulses for the Dega Belt; maize and teff for the Weyna Dega Belt; and sorghum for the Kolla Belt. The agroecological model was further differentiated according to generalised agroclimatic regions, which allowed a fairly precise extrapolation of the field observations into the areas not visited.

In a third step, the resulting geo-referenced map of agroecological belts, which represent major agroecological zones in their vertical distribution, was finally overlaid by the map of the length of growing period (LGP), thus allowing a statistical analysis of the growing periods according to altitudinal zones.

Field verification of the map along major transects (such as roads) will enable the user to make an independent judgement about the precision of the maps. Using frequently travelled routes, the feasibility of the mapped agroecological belts as major agroecological zones (MAZ) can easily be demonstrated. Finally, the map presents a very detailed topographical database which will make possible many computerised applications, including strategic planning, land information systems for different administrative levels, watershed classifications, hydrological process modelling, digital applications of remote sensing data, and even the modelling of synthetic information for which detailed databases may be missing at present.

1 PURPOSE

1.1 Background

Agroecological zonation can be defined as a spatial classification of the landscape into area units with “similar” agricultural and ecological characteristics. There are attributes of such units which determine similarities, such as: (a) comparable agroclimatic conditions for annual cropping, perennial crops, or agroforestry, (b) similar conditions for livestock raising, (c) comparable land resource conditions such as soil, water or vegetative parameters, or (d) similar land management conditions such as raggedness of agricultural land, slope steepness, or topography in general. Such attributes of units determining similarities can further be distinguished according to actual or potential conditions. The former may be used for determining actual agroecological differentiation of farming systems as they persist today. Potential similarities, on the other hand, are concerned more with the assessment of general land capability, or suitability for specific crops.

Usually, agroecological zonation is used to improve the planning of agricultural development, be it in the field of forestry, field cropping, or for livestock management and improvement. Ecological conditions usually relate to climatic parameters, such as amount of rainfall, rainfall variability, temperature or frost hazard, vegetation characteristics (types and composition), whether natural or man-made vegetation, and finally, soil and water characteristics which are further important parameters that permit ecological differentiation.

In mountainous countries the topography, in particular altitude, steepness and slope characteristics, plays an important role in agroecological zonation. In Ethiopia, where the most pronounced mountain system in Africa is found, altitudinal gradients and variability have been recognised as primordial parameters for agroecological zonation. Usually, when it comes to the vertical zonation of major agroecological characteristics in mountains, the term “belt” is used to indicate these altitudinal variations. Altitudinal belt assessments were introduced about 200 years ago. The method was first applied in Latin America through the expeditions of Alexander von Humboldt (1769 – 1859) in the early years of the 19th Century. Von Humboldt observed distinct vegetation belts when leading a bio-geographical expedition along the north-south extension of the Andean Mountains, between 10° N and 10° S. There, distinct vegetational belts could be differentiated from field observations (Humboldt, 1845-1858). Much of this historic methodology was re-used and applied to a large spatial unit in the case of the map on agroecological belts of Ethiopia described in this explanatory note.

This report describes the purpose, objective, methodology, and interpretation of the three maps produced at a scale of 1:1,000,000 and covering the whole of Ethiopia[1.] The maps are the result of an eight-year project carried out in the framework of a collaboration between the Centre for Development and Environment (CDE), the Soil Conservation Research Programme (SCRP), and the Ethiopian Mapping Authority (EMA) between 1987 and 1995. The maps present agroecological belts of Ethiopia, i.e. altitudinal zones which can be defined as ‘major agroecological zones’ (MAZ) of the country. Once defined in this manner, the spatial distribution of the agroecological belts (ABs) was mapped on a newly compiled topographic base map derived from larger-scale maps of EMA, and used to develop a new ‘digital elevation model’ (DEM) in a ‘geographical information system’ (GIS) at CDE, University of Berne, which was the main implementing partner of SCRP from 1981 – 1998.

[1] 8,000 sets of sheets of the maps ‘Ethiopia: Agroecological Belts‘ were mailed to the Watershed Development and Land Use Department (WDLUD) of the Ministry of Agriculture (MoA) in April 1995 and can be requested from there. A very limited number of sets is on stock at CDE in Berne, including the GIS base of the map.

1.2 Traditional altitudinal belts

Because of the importance of altitude in mountain systems, Ethiopian land users have traditionally classified their environment in relation to topography. This traditional denomination is a relative one, although it has some absolute characteristics. Early travellers, such as James Bruce in 1768-1773, used the term 'Kolla' for the 'hotest part of Abyssinia' (Bruce, 1790: Vol. V, Appendix, pp. 67, 69, 149, 186). He also referred to 'Dega' as signifying 'the hill, or high ground' (Bruce, 1790, Vol. III, footnote on p. 387). On one of his maps, he named a small village west of Lake Tana near 'Avolei River' as 'Wainadega' (Bruce, 1790, Vol. V, map 2, and Vol. III, p. 536). Before James Bruce, when the Portuguese travelled to Ethiopia in 1520, no indication of altitudinal belts could be screened from secondary literature (Beckingham and Huntingford, 1961), although again villages called 'Wainadega' were mentioned (see Whiteway, 1902, p. 77). Later travellers like Rohlfs (1883, p. 282) quotes that 'the Abyssinians divide their country into: (a) Kolla, the lowlands, (b) Deka Woina (1,500-3,000 m a.s.l.), and Deka (above 3,000 m a.s.l.)'. On the other hand, Dove (1890) described major agricultural zones in northern Ethiopia more precisely as being ‘Kolla’ at altitudes below 1800 m a.s.l., ‘Weyna Dega’ for altitudes between 1800 – 2400 m, and ‘Dega’ for areas above 2400 m.

Later on, scientists like Huffnagel (1961) confirmed this traditional Ethiopian zonation and added a further zone at high altitudes, called ‘Wurch’, for areas higher than 3800 m a.s.l. That this classification is relative can be confirmed by many examples. In the Simen mountains, a high altitude area of Northern Ethiopia with the country’s highest peak, Ras Dejen (4,533 m a.s.l.), farmers who are living at elevations above 3000 m a.s.l. would say that land users below them live in the Kolla belt, although these villages are as high up as 2800 m a.s.l.. In a ‘normal’ situation in other parts of the highlands, an altitude of 2800 m a.s.l. would itself be called Dega.

Despite the above flexibility in the traditional altitudinal classification, there are certain characteristics which most Ethiopian land users would agree to. In the Wurch zone, usually no rainfed crops would be expected to grow. There, frost is a frequent phenomenon, and afro-alpine grasslands[2] are the dominant land use type if altitudes are not too high even for these perennial or annual grasses. The Dega zone usually is a zone where crops such as barley[3], wheat[4], and pulses[5] are grown. However, no teff[6] and maize[7] would be expected to grow in this belt. Within the Dega, a differentiation can be made between the High Dega belt, where only barley and sometimes potatoes are grown, but no wheat and pulses, and a Lower Dega or "Dega proper" belt, which would additionally allow for wheat and pulses, but still be an area with relatively cold climatic conditions and no teff or maize grown.

The most dominant Ethiopian agricultural belt is called Weyna Dega. All major rainfed crops can be grown in most parts of this belt, particularly teff and maize. This is a belt where both agroclimatic as well as ecological conditions are highly suitable for rainfed farming. The lower part of the Weyna Dega is also suitable for cash crops such as coffee and tea, or for inset[8], another major staple crop of southwestern and southern Ethiopia. The Weyna Dega belt usually has sufficient rainfall, allowing at least one cropping season per year. Below the

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[2] Dominant grass species are *festuca macrophylla, festuca abyssinica, danthonia subulata, poa simensis, while helichrysum citrispinum* bush and *lobelia rhynchopetalum* may also occur.

[3] Barley (Latin: *hordeum vulgare*)

[4] Wheat (Latin: *triticum aestivum*)

[5] Pulses may be, among others, horse bean (Latin: *vicia faba*), pea (*pisum sativum*), or lentil (*lens esculenta*)

[6] Teff is a traditional Ethiopian cereal (Latin: *eragrostis tef)*, which is endemic to Ethiopia and Eritrea (although it is also grown in the U.S.A. today), and occupies about 20% of the cultivated land in Ethiopia .

[7] Maize (Latin: *zea mays*)

[8] Inset or ‚false banana‘ (Latin: *ensete ventricosum)* is a further endemic agricultural plant grown in higher-rainfall regions of the country in the Weyna Dega Belt.

Weyna Dega belt there is the Kolla belt, where there are moisture limitations for crops such as maize, potatoes, wheat and pulses. However, sorghum[9] is a dominant crop in the Kolla belt, and teff and maize will also be grown there if rainfall permits. It is a belt where temperature conditions are much warmer than in the highlands, and where there is a higher rainfall variability and recurring drought conditions. Below the Kolla is the Berha Belt, where no rainfed cultivation is normally possible. Hot temperatures and persistent drought render the area unsuitable for rainfed agriculture, although large-scale irrigation systems along major rivers have been developed in some parts of Ethiopia, particularly along the Awash River.

1.3 Agroecology and agroclimatology

From a scientific point of view, ‘ecology’ is the science of the relationships between living organisms and their abiotic environment, and ‘agroecology ’ particularly relates to agronomic requirements. Another term often used is ‘agroclimatology’, which is the science of long-term weather patterns in relation to agronomic requirements. In most studies in the field of agroecology, a major attempt at agroecological zonation has been made through the application of agroclimatic models and tools. Although agroclimatology only describes one aspect of agroecological zonation, it is the component which has been developed most during the past 20 - 30 years. ‘Zones’ are horizontal spatial units having specific properties (such as agroecology). ‘Belts’, on the other hand, are spatial units which lie between two defined altitudinal boundaries and also have specific properties, similar to the zones.

A number of scientific approaches have been applied in Ethiopia to determine agroecological zones (AZs). Apart from the descriptions of traditional altitudinal belts mentioned above, including a number of other studies relating to vegetation types and farming systems and carried out by Pichi-Zermolli (1957), Mooney (1961), Huffnagel (1961), Westphal (1975), and Amare Getahun (1978), major attempts aiming at the classification of Ethiopia according to altitudinal zones were carried out by FAO/UNDP/LUPRD (1984), Constable[10] (1985) and Hurni[11] (1986), Hurni (1982) for the Simen Mountains, and Mesfin Wolde-Mariam (1990). At the level of mapping, mention must be made of the map ‘Agro ecological zones of Ethiopia’ (1:2,000,000) by Mengistu Negash, Tesfaye Haile, and Tafesse Olcheba (1989), the maps of Tafesse Asres (1996) for south-western Ethiopia, those of Mesfin Wolde-Mariam (1990) for North Shewa and Wello, and the present maps ‘Ethiopia: Agro-ecological Belts’ at the scale of 1:1,000,000 (Hurni, 1995). While Hurni (1982), Mesfin (1991) and Tafesse (1996) presented zonations relating to a section of the country only, Hurni (1986) provided a combination of traditional altitudinal belts and rainfall patterns according to length of growing period as a classification system for the planning of soil and water conservation. This system, nevertheless, has not been applied on a map and was thus not presented in a spatial approach, basically because the topographic source of the country map at that time, with a scale of 1:2,000,000 or 1:1,000,000, did not provide sufficient precision at the time of the establishment of the classification system. As a consequence, these agro-ecological zones were only described as a general pattern, and are presented in Figure 1.

[9] Sorghum (Latin: *sorghum bicolor*)

[10] Constable (1985) defined the Ethiopian highlands to cover all areas above 1,500 m a.s.l., sub-divided into three zones characterised as ‘low potential cereal zone’ (all northeastern highlands), ‘high potential cereal zone’ (basically Gojam, northwestern Shewa and the Arsi-Harerge highlands), and ‘high potential perennial zone’ (southwestern highlands).

[11] Hurni (1986), in his ’Guidelines for Development Agents on Soil Conservation in Ethiopia‘ provided a classification system for Ethiopia according to altitude and length of growing period (in the table referred to as ‘rainfall amounts‘, see Figure 1). The system was used to propose suitable SWC technologies according to these agroecological zones, additionally differentiated according to land use, slope, and soil type. Over 10,000 copies of these guidelines were distributed and widely used over the past 12 years since it appeared.

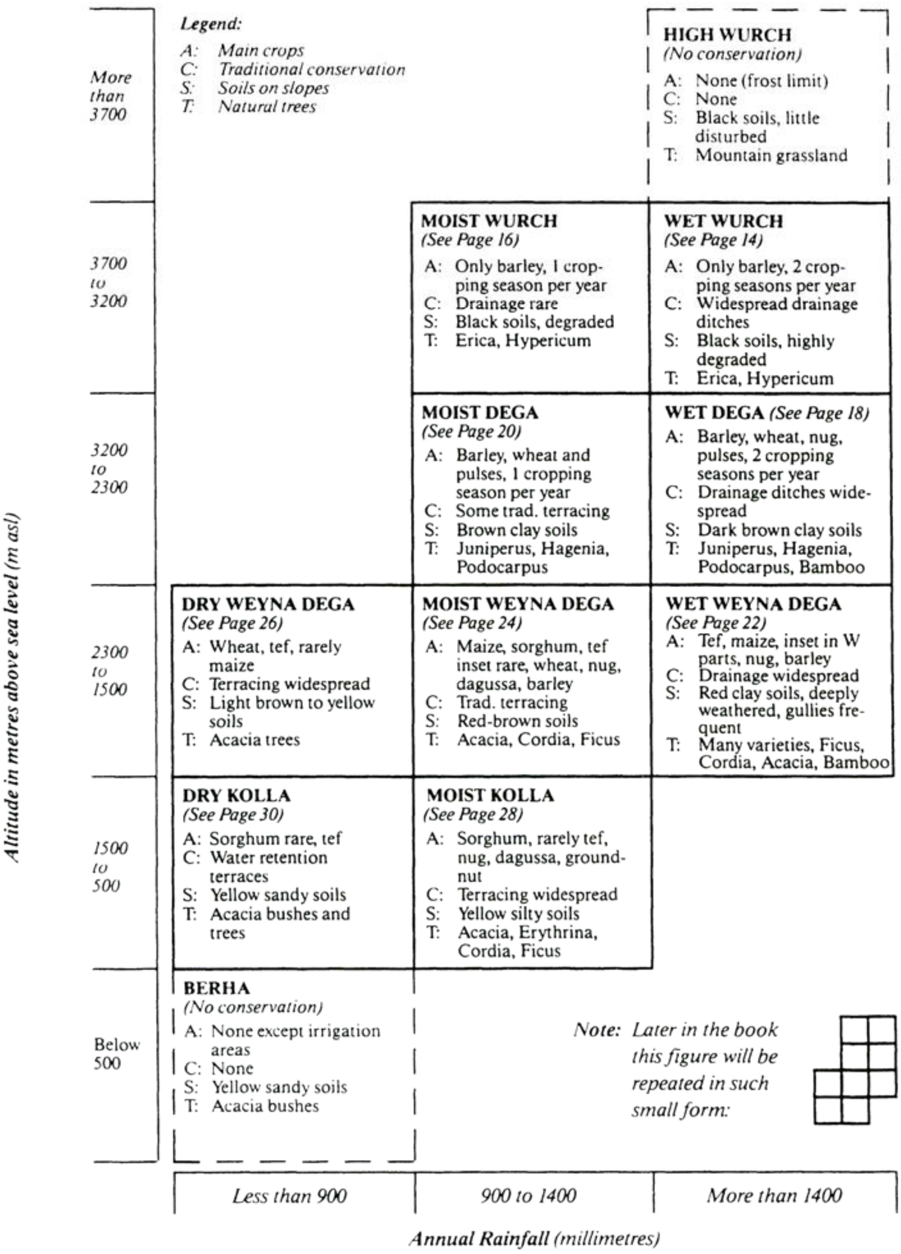

Figure 1. Agroecological zonation system for selecting soil and water conservation (SWC) options in Ethiopia based on field observations (Hurni, 1986)

1.4 Earlier examples of agroecological zonation

A major attempt to carry out an agroecological zonation for the country was taken up by Mengistu Negash et al. (1989) including a map at 1:2,000,000 scale. Principal information for characterising the major agroecological zones (MAZs) and sub-zones was the moisture regime, the thermal regime, and physio-pedomorphic regions of the country. The assessment was based on a number of studies carried out by LUPRD in the late 1970s and early 1980s. The AZs were defined in such a way as to focus on biomass productivity, as well as species composition and distribution of plant communities of an area or a zone. Therefore, climate, soils, and management were taken as basic references. The length of the growing period, determined from rainfall availability and variability, as well as soil conditions, were used as an important input to determine seven conditions of LGP moisture regimes, from arid, semi-arid, sub-moist, moist, sub-humid, humid, to per-humid conditions. These more or less rainfall-dependent characteristics were super-imposed with three thermal conditions of altitude to determine 18 major agro-ecological zones (two arid zones and one very wet zone at high altitude being only theoretically possible in Ethiopia).

One major problem of this AZ model is that although the LUPRD study differentiated between a total of six thermal classes, from hot, warm, tepid, cool, cold to very cold, only three were taken up to differentiate the zones according to altitude. Together with the seven moisture zones, 21 units were determined for Ethiopian conditions, of which three are non-existent, resulting in a total of 18 major agroecological zones (AZ, see Fig. 2 below). These zones were again super-imposed with 9 physiographic regions, namely coastal plains, lowlands, lakes and rift valleys, valley escarpments and lowlands, lowlands and plateaux, plains, plains and plateaux, plateaux, and highlands. As again only a limited number of these combinations exist in Ethiopia's real environment, 62 sub-zones were finally determined. Differentiating these sub-zones, however, becomes difficult when it is realised that the term 'lowlands' is represented three times, 'plains' also three times, and 'plateaux' again three times in three different physiographic regions. Despite this difficult differentiation, the agroecological model of Mengistu et al. (1989) described above is probably one of the most sophisticated and deserves follow-up.

There are, however, two major problems resulting in considerable limitations of the 'agro ecological map' by Mengistu et al. (1989). The first major problem is that there were obvious difficulties when delimiting the different zones and sub-zones on the map. Since the topographical base used was a map at a scale of 1:2,000,000 which had been derived from old sources and contains considerable topographical errors (cf. Annex I), application of the model on a map would have to be done again. For example, one single MAZ includes the highest mountain of Ethiopia (Ras Dejen at 4,533 m a.s.l.) and extends as far down as the Tekeze River at 1,000 m a.s.l., in a vertical interval of 3,500 m, thus encompassing at least 4-5 different agroecological belts from the afro-alpine grassland to the intra-montane desert along the Tekeze River. Field verification of this mapping will certainly be necessary, but could easily be enhanced with the present model and a new digital elevation model based on GIS, as it was used for the AB maps described in this explanatory note.

A second major problem persisting in the agroecological model of Mengistu et al. (1989) is the fact that the six original altitudinal thermal zones were reduced to three 'generalised thermal zones' (p. 12) in the final model. For example, 'hot' and 'warm' temperatures (at altitudes below 1600 m a.s.l.) were put together, which means that conditions of the Kolla and Berha Belts were combined, although there is rainfed agriculture in the Kolla Belt, but not in the Berha Belt. The same applies to the tepid and cool temperature regimes from 11-21° C, describing the altitudinal zone between about 1,600 and about 3,200 m a.s.l.. This is a very

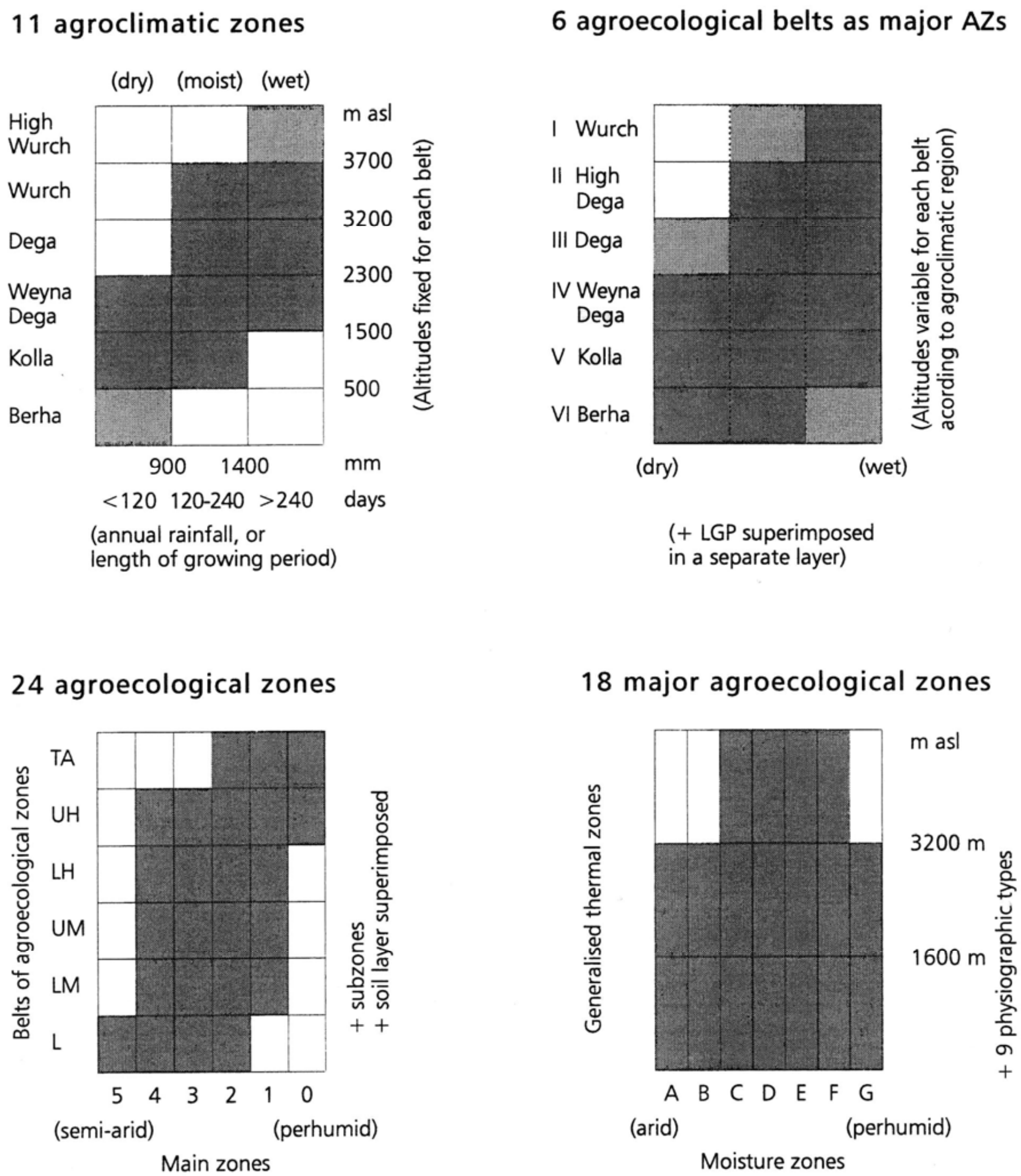

Figure 2. *A schematic comparison between four agroecological models applied for Ethiopia. Top left: Hurni, 1986; top right: Hurni, 1995; bottom left: Tafesse Asres, 1996; bottom right: Mengistu et al., 1989.*

huge altitudinal zone which in reality contains a very strong agroecological differentiation in this major agricultural belt of Ethiopia. For example, maize and teff cultivation will not reach up to the highest thermal limit of this zone, but have its upper limit at about 2,400 – 2,600 m a.s.l.. Failing to differentiate such an important altitudinal boundary between Weyna Dega and Dega means that the agroecological model lacks a basis for delimiting maize and teff from the other Dega crops. The same applies to the highest thermal class, namely cold to very cold temperature regimes. This is an area delimiting virtually all altitudes above 3,200 m from those below. Nevertheless, there are annual crops grown at altitudes from 3,200 to 3,800 m a.s.l., while only grasslands persist above that boundary. Again, a very important agroecological boundary, namely the upper limitation of barley and potato cropping cannot be made based on the agroecological model by Mengistu et al. (1989). As a consequence, AZ map of Ethiopia would have to be revised not only because of the erroneous geo-referenced application, but also because of its present setting of the boundaries of the thermal (altitudinal) zones.

Another very interesting agroecological zonation was produced by Tafese Asres (1996) for Southwest Ethiopia, namely for the former provinces of Illubabor, Kefa, Wellega and Assosa. Tafese again used the agroclimatic modelling approach and differentiated between six altitudinal agroecological zones, namely lowlands, lower midlands, upper midlands, lower highlands, upper highlands, and tropical alpine zones. Each of these main belts is differentiated according to moisture conditions, from per-humid, humid, sub-humid, semi-humid, transitional, to semi-arid conditions. Although potentially there would be 36 sub-zones, only 24 were used to characterise Southwest Ethiopia. The result is a highly differentiated zonation model which was applied on a fairly precise topographic base map. In particular, the altitudinal zones for areas between about 1,000 and about 2,800 m a.s.l. are very well differentiated and allow for a rather precise location of major subzones suitable for coffee and chat[12] in the Weyna Dega Belt. Unfortunately, despite its general scale of 1:500,000, the map again used a rather general topographical basis, which could sometimes be improved. The model, however, has been carefully developed and presents an adequate system for Southwest Ethiopia.

In conclusion from the past assessments of agroecological zones in Ethiopia, four major messages can be drawn:

1. All studies confirm the importance of altitudes above sea level (a.s.l.) as the primary denominator of agroecological zonation.
2. When it comes to a spatial application of the models, the importance of a precise digital elevation model (DEM) or topographical basis was recognised.
3. Having sufficient climatic data for statistical modelling was reiterated as a most important prerequisite when determining agroclimatic conditions for agroecological zonation.
4. It appears important that field verification is made when models have been developed and applied to spatial units on maps.

The agroecological belt map for the whole of Ethiopia at a scale 1:1,000,000 presented in this explanatory note is considered a major step towards an area-specific, i.e. precise, location of major altitudinal zones in map form. Once this is based on a sound differentiation of agrothermal altitudinal limits and realistic field boundaries, the map can easily be further differentiated at a later stage for specific conditions of crops, livestock, or forestry in the country, by producing subdivisions of agroecological zones in each belt.

[12] Chat (Latin: *catha edulis)* is a bush containing alcaloid and its leaves are consumed by humans and animals as a stimulant and drug. It occurs is in the Weyna Dega Belt all over Ethiopia.

2. APPROACH

2.1 Objective, explanations and limitations

The general objective of the Agroecological Belts Map of Ethiopia, scale 1:1,000,000, is to produce a precise, geo-referenced overview of 'major agroecological zones (MAZ)' of Ethiopia based on an improved digital elevation model (DEM) and altitudinal zonation of traditional rainfed cropping patterns as primary denominators of the belts.

The term 'geo-referenced' relates to the application of the model to as precise a topographical model of Ethiopia as possible. This was a major goal and task for the present project. For the Ethiopian mountain system, agroecological belts (ABs) have been defined as MAZ in this model. Due to the lack of sufficient measurements and data on temperature in Ethiopia, these MAZ were determined with the help of field observations of farming systems and specific crops throughout Ethiopia. The agroecological model determining ABs has thus not been derived from meteorological data, but from field observations of traditional boundaries of rainfed crops. These observations were later on extrapolated to larger areas where similar rainfall patterns were assumed to occur.

The main reason for not applying a climatic model must thus be seen in the fact that there is only very limited information on agroecologically relevant temperature measurements which could be used for the vertical delimitation of belts as MAZ. Even the sophisticated rainfall information from more than 200 stations in Ethiopia may not be detailed enough to provide statistically significant altitudinal models of rainfall regimes. For example, in his attempt to differentiate rainfall and altitude, Helden (1988) could not derive a rainfall model applicable to the whole of Ethiopia. Although the statistical approach may be refined in future modelling for the whole of the country, this would be a difficult task with the data presently available.

In the present map, soil and water conditions have not been included in the model. This is because of the map scale (1:1,000,000) which does not allow site specificity and local conditions to be shown. However, in the GIS available with SCRP and CDE, local soil and slope conditions can be modelled as additional layers at any time and for any given purpose. Again, natural vegetation types (either actual or potential) were not included in the modelling, although there exists a strong correlation between patterns of annual cropping systems and potential natural vegetation types. Also, moisture regimes are not shown on the main map. However, as a further differentiation of these MAZ as altitudinal belts, a statistical analysis was made by overlaying the MAZ with the map 'Lengths of growing periods' (LGP, scale 1:2 million) in the GIS, and the results presented in small maps and table form on the margins of the maps. Presentation on the large maps was not possible because the LGP map of LUPRD had a weak topographical base and the information is thus of limited statistical value and relevance.

2.2 Steps in the development of the maps

The production of the agroecological belts (ABs) map of Ethiopia in three sheets is based on a two-fold approach. The first component consists of the development of a new topographical base map at a scale of 1:1,000,000. This had to be derived from an appropriate data-base and put into a DEM for the whole of the country. The second component consists of a field based empirical model to delimit vertical MAZ, i.e. agroecological belts, from field observations of cropping patterns and major species of annual rainfed crops. The third component consists of the statistical analysis and presentation in table form on the maps.

The following five steps were applied to produce the maps:

1. Starting from the farming systems which exist in Ethiopia as a basis for delimiting traditional altitudinal zones, the occurrence of traditional rainfed crops such as barley, potatoes, wheat, pulses, tef, maize and sorghum was used to find boundaries between typical cropping systems in Ethiopia. These typical cropping systems could be associated with the traditional altitudinal terms: Wurch, High Dega, Dega, Weyna Dega, Kolla, and Berha.
2. A precise topographic source map at 1:1,000,000 scale, with 200 meter contours, was produced and computerised into a DEM for the whole of Ethiopia.
3. Extensive field mapping of the occurrence of major agricultural rainfed crops, carried out throughout the country in the period from 1974 to 1993, was used to find out characteristics of these altitudinal zones in the different parts of the highlands. Agroecological belts were then derived from these observations and differentiated according to different regions of Ethiopia using region-specific models.
4. This agroecological belt model was extrapolated from transect to larger areas using ‘agroclimatic regions’ as areas of applicability, which were derived from available information on rainfall patterns and cropping seasons.
5. The different models for each agroclimatic region were applied to the DEM of the GIS in order to produce a very precise spatial differentiation of vertical agroecological belts in Ethiopia presented on the maps.

2.3 Illustration of the applicability of the maps

The agroecological belts map may be verified by the reader along transects which are commonly known in Ethiopia. Three examples shall illustrate the relative precision of the agroecological information that can be read from the maps: the road transects from Addis Abeba to Dese, from Gonder to Axum, and from Nekemte to Gambela.

Along the road from Addis Abeba to Dese, the following agroecological belts are crossed: in the area between Addis Abeba and Sendafa, the Weyna Dega Belt persists, with tef and all other crops existing side by side. After Sendafa, the road enters the Dega Belt from Aleltu to Tarmaber, where no tef is grown, but mainly wheat, pulses and barley are grown besides oats. Near the tunnel to Debre Sina, the road enters into the High Dega belt where only barley is grown. A small area of Wurch can be seen to the right of the road near Godo Beret village. After the tunnel and down to Debre Sina and Armanya, the road again crosses the very fertile Weyna Dega Belt. In Shewa Robit, the Kolla Belt is reached, where irrigation is used as supplementary means to produce crops which otherwise would not grow in this area: fruit trees, sugar cane, and maize. Passing Shewa Robit the road reaches the Berha Belt in Jewaha, although it mainly follows the Kolla belt until near Kombolcha. The Borkena Valley is characterised by Weyna Dega on its slopes, and Kolla on the valley bottom. Near Kombolcha the road enters again into the Weyna Dega Belt, which has all crops persisting, including tef. Climbing up to Dese, the Dega Belt is again reached, where wheat, barley and pulses dominate.

A second example is the agroecology along the road from Gonder to Axum. From Gonder, the road passes through the Weyna Dega belt, but soon reaches the Dega belt near Amba Giyorgis, in which it remains all through Wegera area, crossing the towns of Dabat, Wekin, and Debark. These highlands are characterised by fertile soils and wheat, pulses and barley as major crops. Past Lemalimo on the escarpment north of Debark, the road enters into the Weyna Dega Belt near Dib Bahir, but soon reaches the Kolla Belt in Zarima, where it remains for a major part of the road along to Adi Arkay and May Tsamri in Tigray Region. Past this, the road enters into the Berha Belt in the lowlands of the Tekeze River, which it crosses at about 1,000 m a.s.l.. Back up on the northern side of Tekeze River, the road crosses the Kolla Belt and enters into the Weyna Dega Belt in Inda Baguna, which it will not leave until Axum is reached. Here again, tef and maize can be grown if moisture is sufficient.

As a third example the road from Nekemte to Gambela is taken. In Nekemte, the Weyna Dega Belt is dominant throughout the area, until down to the Didesa Valley where there is a narrow strip of Kolla Belt. Back up to Gimbi and onwards to Dembidollo, the road crosses through various sub-zones of the Weyna Dega Belt not further differentiated on the map. When the road passes above 2,000 m, however, coffee would not be found, but when it goes below that level, coffee and inset would be frequently grown. Past Dembidollo, the road descends towards the lowlands, crossing the Kolla Belt, and finally entering into a transitional moisture belt below 600 m a.s.l. which was mapped as Berha Belt. Although the term ‘Berha’ means desert, the Gambela conditions have more moisture and are inundated part of the year, so that their appearance would not resemble a desert. However, the area does have a pronounced dry period in the dry season, so that semi-arid conditions persist to a strong degree. Furthermore, temperatures are very hot, which may justify the term ‘Berha’ even here.

These examples have shown how the maps can be interpreted location by location due to their precise topographical basis, and the agroecological information about these vertical belts representing major cropping patterns appears to be close to reality in Ethiopia.

3. METHODOLOGY

3.1 Overview

Figures 3a and 3b below present a flow chart of the methodological procedure for developing the agroecological belt map of Ethiopia. The methodology consists of three major parts, namely the production of a new topographical map of Ethiopia, and second, the application of a field-based agroecological model for vertical differentiation of MAZ into ABs, and third, the statistical analysis.

The main database for producing the agroecological maps consisted of base maps of EMA at a scale of 1:250,000, complemented by other maps covering areas along international boundaries, plus supplementary information from maps at a scale of 1:50,000. In addition, documents of agroclimatic zonation of Ethiopia (FAO/UNDP/LUPRD 1983) as well as the map 'lengths of growing periods', at a scale of 1:2,000,000 were used. The main database, however, is field observations of traditional farming systems and altitudinal belts in Ethiopia observed throughout the country over a period of 20 years, from 1974 to 1993 by the author. The production of the topographic map is a 7-year project between SCRP, CDE and EMA (1987-1994). Field transect observations and respective cross-sectional mapping allowed production of a generalised altitudinal agroecological belt model for different agroclimatic regions of Ethiopia. This could then be applied on the new topographic map and analysed by GIS procedures for statistical tables of different content.

3.2 Topographic base map

A major shortcoming at the beginning of the project in 1987 was the non-existence of an appropriate topographic base map for Ethiopia at a scale 1.1,000,000. There existed a map at a scale of 1.2,000,000 which was used for most overview purposes, including the results of LUPRD. However, this base map contained contours which were derived from old sources and had enormous errors in topography (see example in Annex I). For example, certain mountain tops had altitudinal errors up to 300 metres, while other areas were simply not mapped to scale. These errors could be visually detected with some field experience. Detailed investigations with the EMA maps at 1:250,000 scales for the whole of the country showed that these errors were considerable and led to wrong interpretations and alignments of boundaries. It was thus decided to re-design a new topographical base for Ethiopia based on the 1:250,000 maps. An earlier version of such a map was produced by EMA and consisted of 11 sheets. However, the contour intervals on these sheets were at 500 meters vertical interval only. This could not be used for a precise DEM because of the large vertical difference between two contours. At a scale of 1:1,000,000,000, two-hundred meter contours were considered appropriate.

EMA supplemented 37 1:250,000 maps for deriving the new contour model for the whole of the country. An overview of the map coverage of these 37 maps is given in Figure 4. For areas along the Ethiopian boundary which were not covered by these maps, other sources and maps were supplemented by EMA and used. The procedure was to redraw by hand, on transparent paper, the 200 meter contours of these maps including rivers, and to compose these maps into a new composite map which was reduced by a factor 4. Once the composite map was completed, it was copied and scribed into a new map 1:1,000,000. On a separate layer, the river system of Ethiopia was also scribed. Both, this 200 meter contour layer as well as the

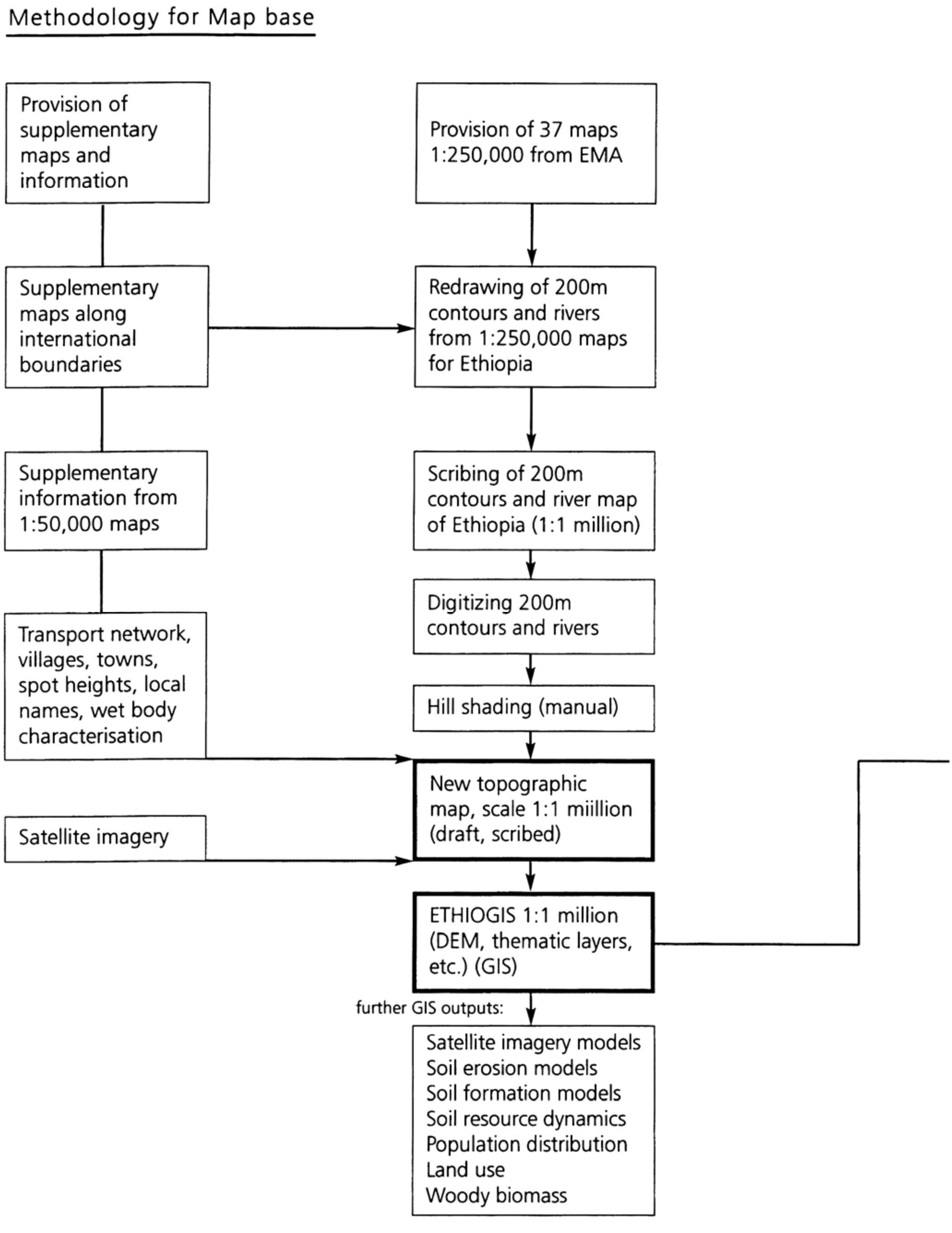

Figure 3a. Flow-chart and methodological procedure for developing the agroecological belt map of Ethiopia.

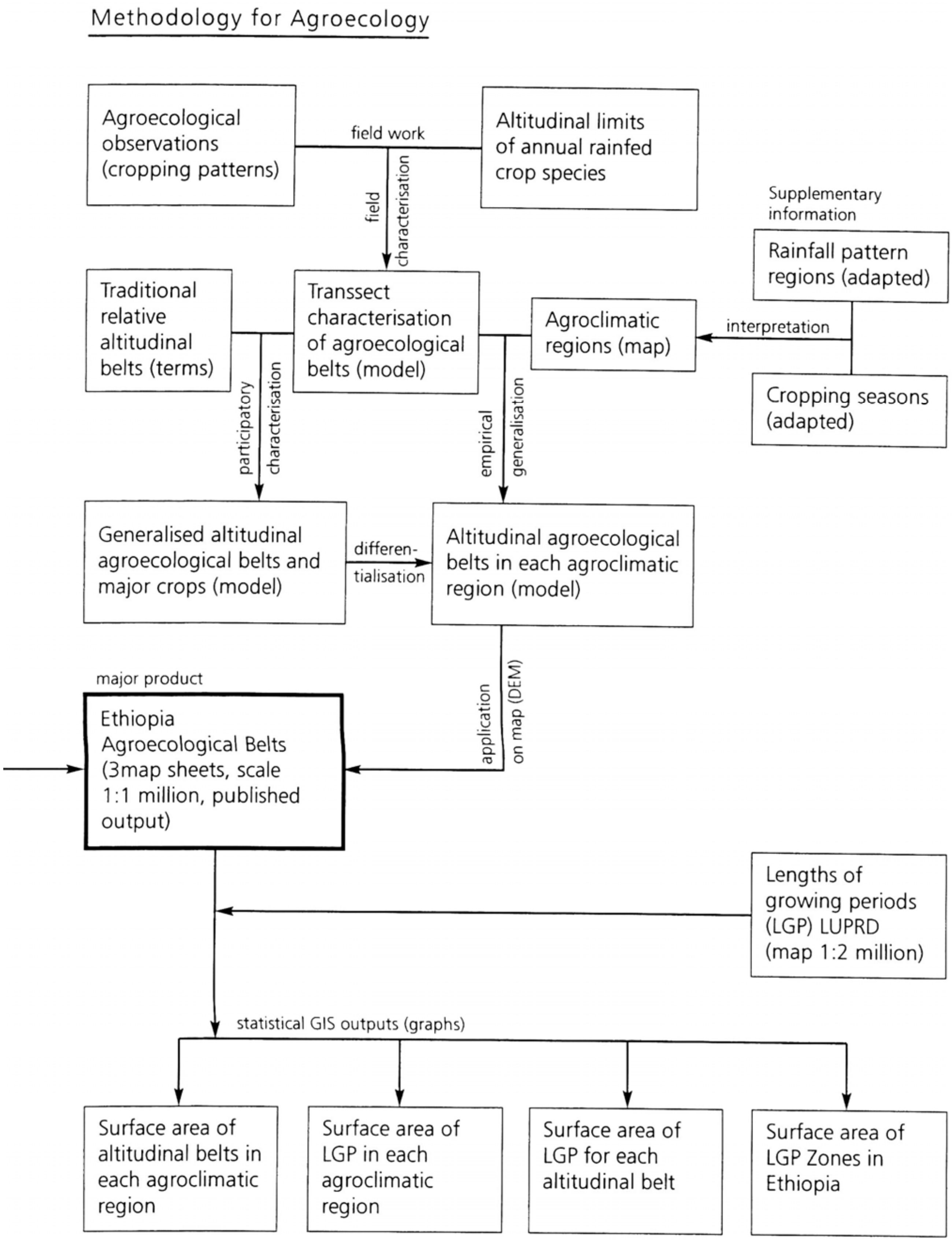

Figure 3b. Flow-chart and methodological procedure for developing the agroecological belt map of Ethiopia.

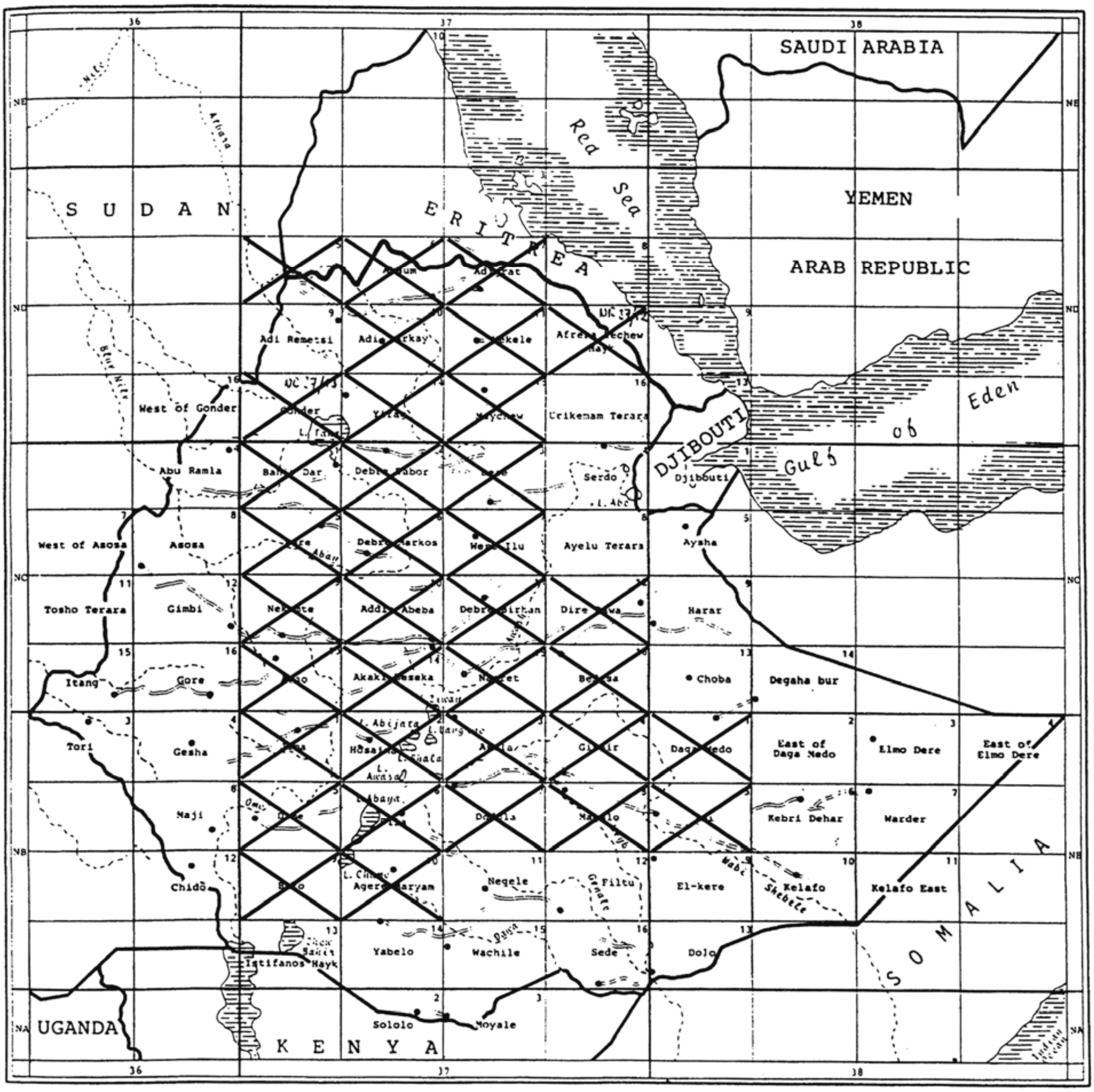

Figure 4. *Overview of the topographic source at a scale 1:250,000 used for the DEM and new topographic base map 1:1 million. Maps not marked were supplemented by EMA in the form of a re-drawn 200m contour sketch map for digitising at CDE.*

layer of the river system were later digitised and entered into a GIS (Arc Info) at GIUB. EMA additionally supplemented maps relating to transport network, villages, towns, spot heights, names, as well as different types of wet bodies for the country. These elements were put together to produce a new topographic map at a scale of 1:1,000,000. Satellite imagery as well as the topography was finally used to draw a hill shading for Ethiopia, again by hand. This work was carried out by Mr. Helmut Terwey who had been affiliated to the Swiss Mapping Authority. Finally, the topographic map of Ethiopia was separated into three sheets, a Southwestern, Southeastern, and a Northern sheet which partly overlaps with the former two sheets. Figure 5 presents an overview of the composition of sheets.

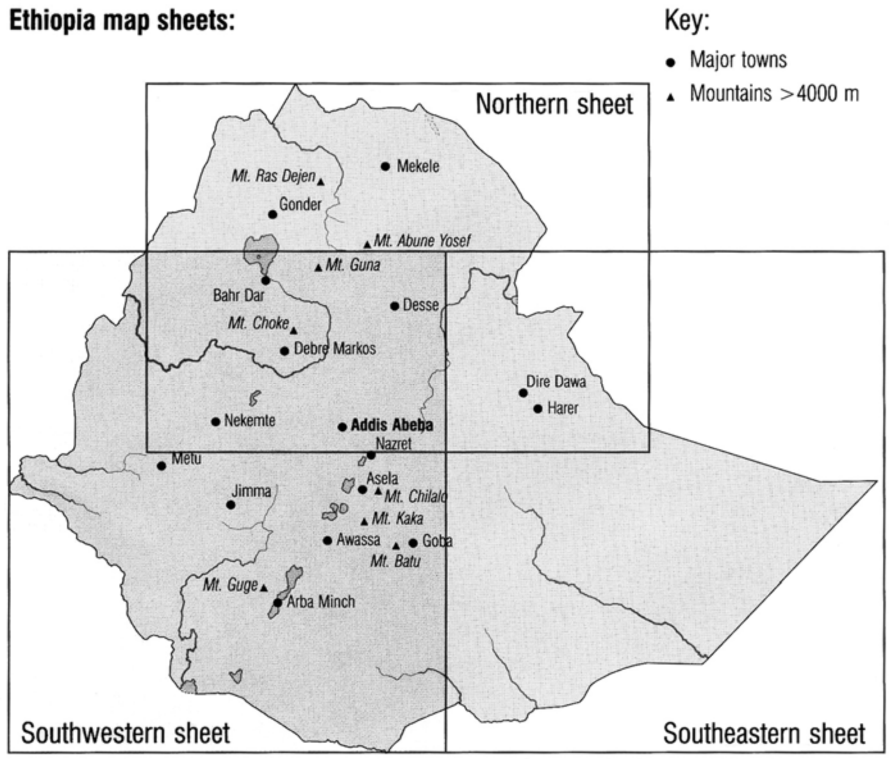

Figure 5. Overview of the composition of three sheets of the agroecological map of Ethiopia.

At the same time the different layers were put on GIS, including thematic information. Further GIS outputs which combined the topographic map with satellite imagery models showed that this new DEM of Ethiopia provides the greatest accuracy at scales from 1:200,000 up to 1:2,000,000. An important gap for presenting Ethiopia in overview form was closed in 1993 when the EMA project was completed. Due to uncertainties about administrative boundaries in these years, no regional boundaries were put on the map. However, area names such as those of former provinces, as well as a new set of broader local names, were printed on the map for easier reference. Once administrative boundaries are clearly defined on 1:250,000 scale maps, this gap can easily be closed in the DEM for Ethiopia, and can be used for planning purposes at regional as well as Wereda levels. Similarly, the DEM can be used for soil erosion modelling, soil formation modelling, soil resource dynamic assessments, population distribution, land use and woody biomass mapping, strategic planning for sustainable land management, and soil fertility improvements, and many other potential applications. National planning would thus be facilitated to a high degree with the present map and DEM.

3.3 Agroecological approach

As shown in Figure 3 of Section 3.1., the agroecological approach basically consisted of field observations of cropping patterns and altitudinal limits of annual rainfed crop species. These are presented in Figure 6 below.

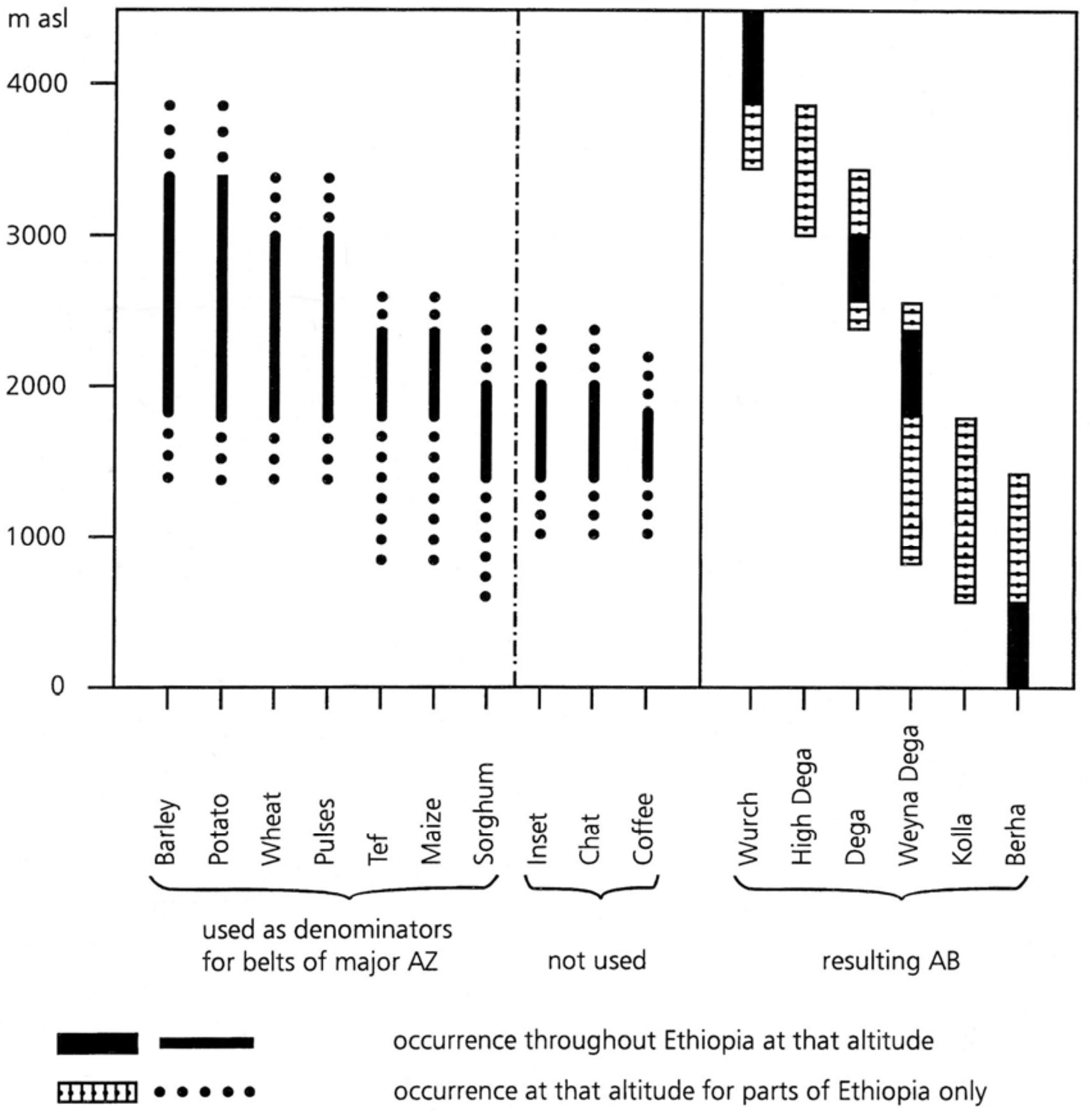

Figure 6. *Vertical occurrence of major agricultural rainfed crops (left) and resulting Agro-ecological Belts (AB, right side) representing MAZ of Ethiopia.*

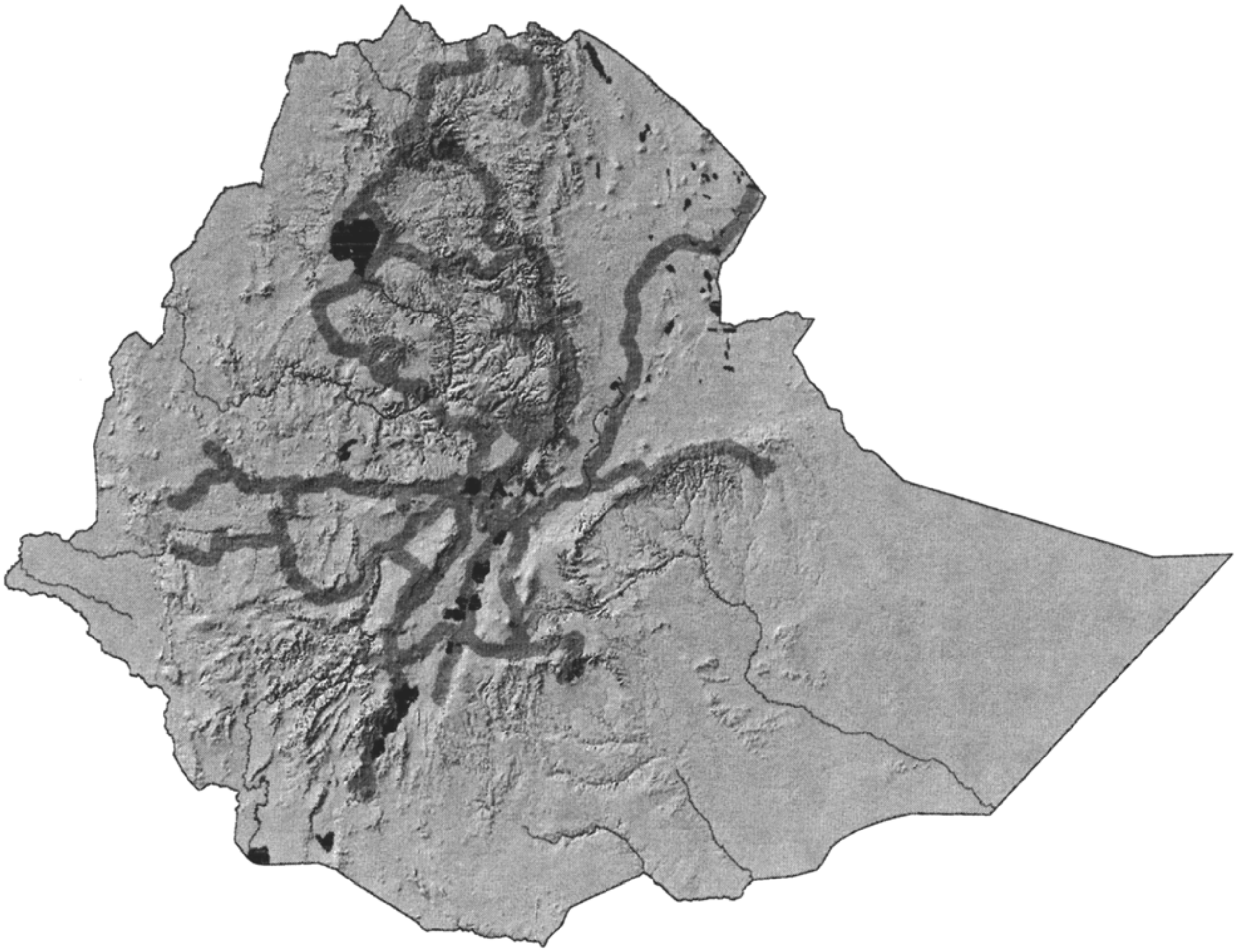

Figure 7. Overview of field observations by the author throughout the highlands between 1974 and 1993. It is assumed that on the average, 10 km of area could be overlooked on either side of the transect in a mountainous environment. Statistical data is given in Table 1.

The following major crops were observed in most agroclimatic regions of Ethiopia: barley, potato, wheat, pulses, tef, maize, and sorghum. The occurrence and altitudinal limits of inset, chat, and coffee, on the other hand, were not particularly registered. These would be useful additions when a differentiation of the Weyna Dega Belt into sub-belts is attempted. However, in this presentation, they were ignored.

From field observations over a period of 20 years (1974-1993) it was possible to derive a characterisation of major agroecological belts in the different transects. Figure 7 and Table 1 show that the author had insight into an area representing 11.4% of Ethiopia's landscape. While he could actually make observations over about half of the Wurch (51%) and High Dega (48%) Belts, and about 41% and 23% of the Dega and Weyna Dega Belts, respectively, he obtained much less insight into the lowland areas, where he could only see about 6% of the Kolla Belt, and only 2.5% of the Berha Belt.

TABLE 1
Overview of transect area observed in each agroecological belt (AB) and agroclimatic region by the author, 1974-1993, in percent of total areas (%).

	Agroclimatic Region								
Agroclimatic Belt	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**TOTAL**
I (Wurch)	14,52	80,72	46,52	48,86	0,70	8,43	84,25	99,53	51,27
II (High Dega)	13,39	71,09	47,06	27,67	8,61	24,57	78,52	99,00	48,07
III (Dega)	32,31	50,94	19,51	19,01	17,95	40,36	35,17	84,13	40,64
IV (Weyna Dega)	24,26	35,04	13,99	9,55	18,57	25,72	21,31	39,09	23,32
V (Kolla)	7,76	29,51	2,87	0,01	3,04	0,06	0,38	10,37	5,70
VI (Berha)	0,91	14,50	0,07	0,00	0,19	0,00	0,00	1,58	2,51
Lakes	0,66	22,73	0,00	0,00	34,00	42,46	12,08	0,00	23,13
Total	**11,10**	**25,27**	**1,54**	**3,29**	**9,63**	**20,89**	**14,74**	**18,18**	**11,44**

In the field it was realised that the highlands do not have similar altitudinal limits on their eastern, western, northern or southern sides. Particularly towards the west, altitudinal belts appear to be much lower than towards the east and north. The same applies to southern parts. Again, a difference was observed between intra-montane valleys such as the Tekeze River in the north, the Abeya River in the west, and the Omo-Gibe River in the south. It was thus necessary to make a transect characterisation of these main belts according to the different regions. Through this characterisation it was possible to relate the transect observations with traditional (relational) altitudinal belts and produce a generalised model of altitudinal agroecological zones and major crops (cf. Figure 9). When attempting to differentiate this generalised model, it was found that it is possible to do this step with the help of a very generalised

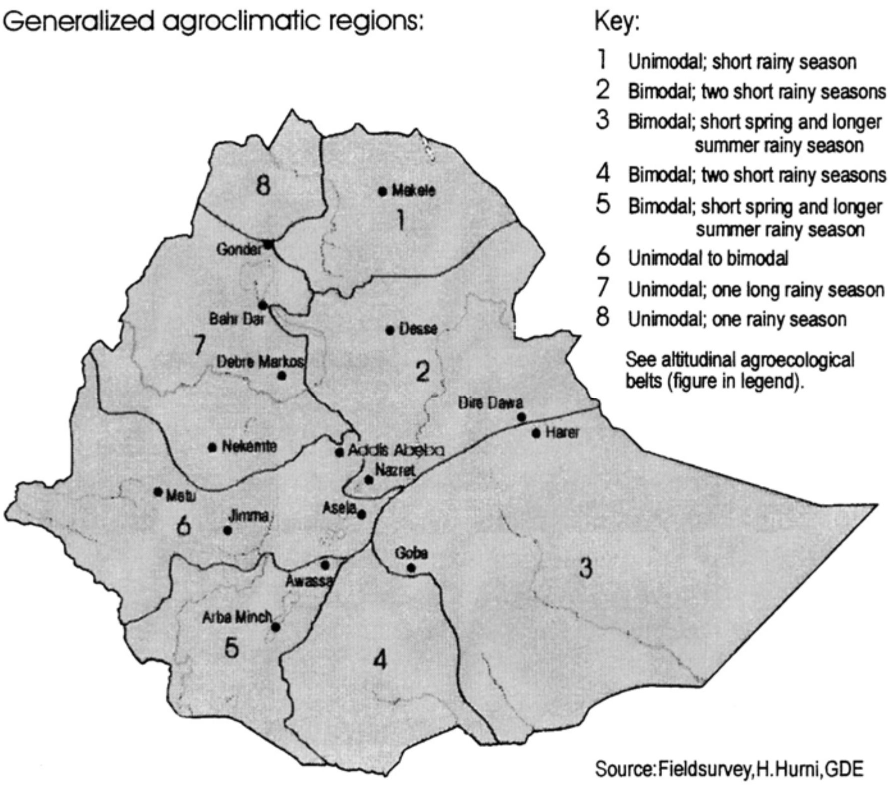

Figure 8. *Generalised agroclimatic regions of Ethiopia as used to extrapolate transect models of ABs in each region.*

agroclimatic regionalisation of Ethiopia. Agroclimatic regions would on the one hand be composed using generalised rainfall pattern regions and the transects, and on the other hand adapted to generalised cropping seasons. This supplementary information (cf. Figure 8) was used to do an interpretation of agroclimatic regions. Combined together, the altitudinal agroecological belt model (Fig. 9 below) and the agroclimatic region delimitation were used to apply the 8 different models to the new topographic sheet of Ethiopia, and to produce the agroecological belt map. This is the major published output of agroecological zonation in map form.

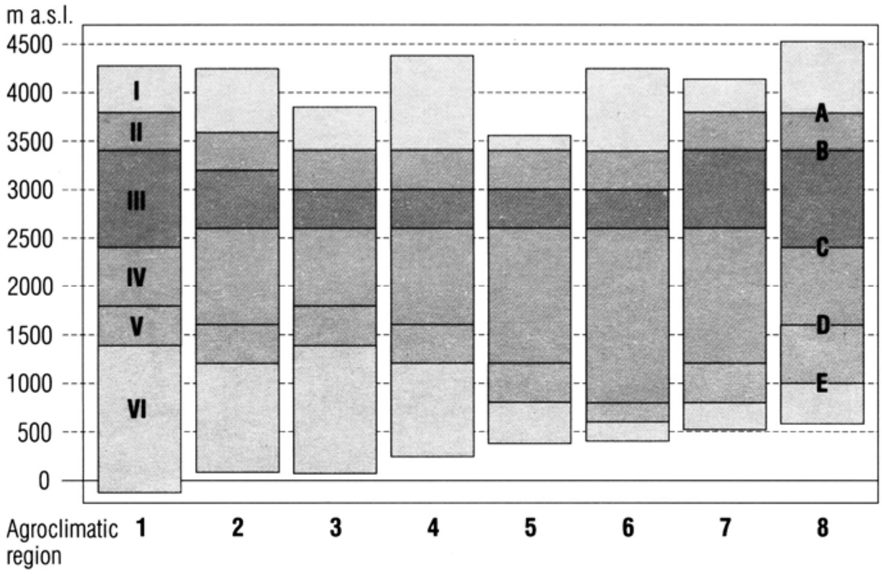

Figure 9. Model of Agroecological Belts (AB) applied to Agroclimatic Regions of Ethiopia (Field survey, H.Hurni, GDE)

TABLE 2

Area coverage for each agroecological belt (AB) in Ethiopia, sub-divided into different agroclimatic regions (see Fig. 9), in 1,000 km²

	Agroclimatic region of Ethiopia								
AB [1000 km²]	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	***Sum***
I (Wurch)	0,05	0,32	0,94	0,86	0,00	0,35	0,09	0,24	*2,85*
II (High Dega)	0,26	2,45	1,19	1,02	0,34	1,88	0,36	0,41	*7,89*
III (Dega)	7,80	14,14	2,58	3,85	1,38	6,11	6,68	2,92	*45,47*
IV (Weyna Dega)	24,56	38,41	18,80	21,53	35,68	106,85	90,39	5,89	*342,11*
V (Kolla)	16,85	19,38	32,75	36,63	25,85	6,90	30,27	15,85	*184,47*
VI (Berha)	41,81	87,90	285,29	42,19	23,25	24,91	21,42	14,74	*541,50*
Lakes	0,62	1,32	0,00	0,00	2,35	1,18	3,31	0,00	*8,78*
Sum	***91,94***	***163,92***	***341,55***	***106,07***	***88,86***	***148,17***	***152,52***	***40,04***	***1133,08***

Note: The total area for Ethiopia (lakes and land) was calculated by GIS to be 1,133,080 km². However, the total area given on the maps, scale 1:1,000,000 and produced in 1995, is about 3% less. This is due to (a) an adjustment of international boundaries between Eritrea and Ethiopia since then, and (b) older total area estimates taken as 'official' at that time.

3.4 Statistical approach

No attempt was made to further differentiate the vertical MAZ or ABs into more refined agroecological zones, e.g. by introducing a climatic analysis and doing a sub-classification for the whole of the country. However, a very generalised analysis was made by combining the Length of growing periods (LGP) map, at a scale of 1:2,000,000, with the present AB map, at a scale of 1:1,000,000. Because of the different scales and the topographical shortcomings of the LGP, these boundaries were not put into the larger-scale map. Nevertheless, a statistical output was produced by applying the LGP map with the AB map in a combined overlay. Based on this composite map, different surface areas in square kilometres could be calculated for altitudinal ABs in each agroclimatic region, for the surface area of LGP in each agroclimatic region and in each agroecological AB, as well as the surface area of LGP zones in Ethiopia. These four statistical products are presented in graph form, including surface area measurements, on each map for the respective map sheet, as well as for the whole of the country.

Thus, it was possible to produce precise area calculations based on the AB map on very precise topography, and a more generalised LGP map for Ethiopia. No attempt was made to differentiate the LGP into many sub-classes because of the shaky application of the LGP map with its topography. Once this is improved, it should be fairly easy to make a more differentiated AZ map for the whole of the country, based on the altitudinal boundaries given on this agroecological belt map. However, at present, the maps as they are produced and presented already provide a very good overview of the vertical agroecological zones of the country.

4. INTERPRETATION

4.1 General impressions

When looking at the composite map of the three sheets covering the whole of Ethiopia, one quickly realises two major features (see also Annex II). A major part of the country is covered by so-called lowland areas in semi-humid, semi-arid and arid conditions (coloured brown-yellow, or grey in Annex II). These are generally named Berha in Amharic, meaning “desert” conditions. Nevertheless, there are certain transitional areas such as the western Ethiopian lowlands of Gambela, where the term desert would not be appropriate. There, “transitional lowlands” would be a term to use. Much of Gambela is seasonally flooded and thus quite unsuitable for permanent agriculture. There is also a pronounced dry season which makes the area transitional between semi-humid and semi-arid. The rest of the Berha area, however, can be clearly called a desert area. Almost 50% of the present Ethiopian territory is situated in this MAZ at low elevations.

The second major observation from the composite map and Annex II is that most of the highlands are coloured in green to bluish colours. There are two shades of green which denominate Weyna Dega and Dega areas and cover about one third of the country (35%). The remaining part of the highlands, namely about one sixth of the country, is Kolla, in olive colour (brown in Annex II), situated between the Berha and the Weyna Dega belts. Many of the valleys, such as the Abeya and the Omo Gibe, are in these colours because of their intra-montane dry and hot situation. The commonly known beneficial highland climate, including valleys and plains, is thus the main habitat of the Ethiopian land users, because agroclimatically, it is highly suitable for rainfed cropping. The Weyna Dega belt alone covers about 30% of the country, of which most is moist to wet. Bluish to light grey colours show highland peaks of Ethiopia where only barley can be grown or where alpine grasslands persist. These, however, only make up roughly 1% of the country. On the other hand, they are important biodiversity areas and characterise the highland peaks which mostly originate from ancient volcanoes. An extremely large surface coverage of Weyna Dega is in the southwest of the country. This dominant AB could be subdivided into a lower belt where coffee is grown, and a higher belt where tea and chat can still be grown. However, on this general map for the whole of Ethiopia, Weyna Dega was not vertically subdivided any further.

A further interesting analysis can be made from the LGP map (cf. Fig. 10 and Tab. 3). From the statistics it can be derived that about 40% of the country has a length of growing period of less than 120 days per year, while another 40% is moist with 120-240 days of growing period per year. Only about 20% has a wet climate, with over 240 days of LGP per year. Higher parts of Ethiopia are largely situated in the moist to wet moisture regimes, while lower parts are clearly situated primarily in the moist to dry regimes.

A further important characterisation can be read from the overview legend of the maps. It shows that in the agroclimatic zones 5, 6, 7 and 8, namely in the south-western, western and north-western parts of the country, the Weyna Dega and Kolla Belts extend much further down than in the eastern parts of the country (cf. Figure 9). This is due to rainfall regime and moisture availability, and has considerable influence on the occurrence of rainfed agriculture. Along the eastern escarpment, the lower boundary of such agriculture extends to roughly 1,200 m a.s.l., while in the western parts of Ethiopia, rainfed agriculture can be as low as 600 m a.s.l. This is a very important asymmetry of vertical MAZ between the east and the west side of the highlands. Another asymmetry can be observed between north and south when following the occurrence of the ‘High Dega’ Belt. In the southern parts of the Ethiopian

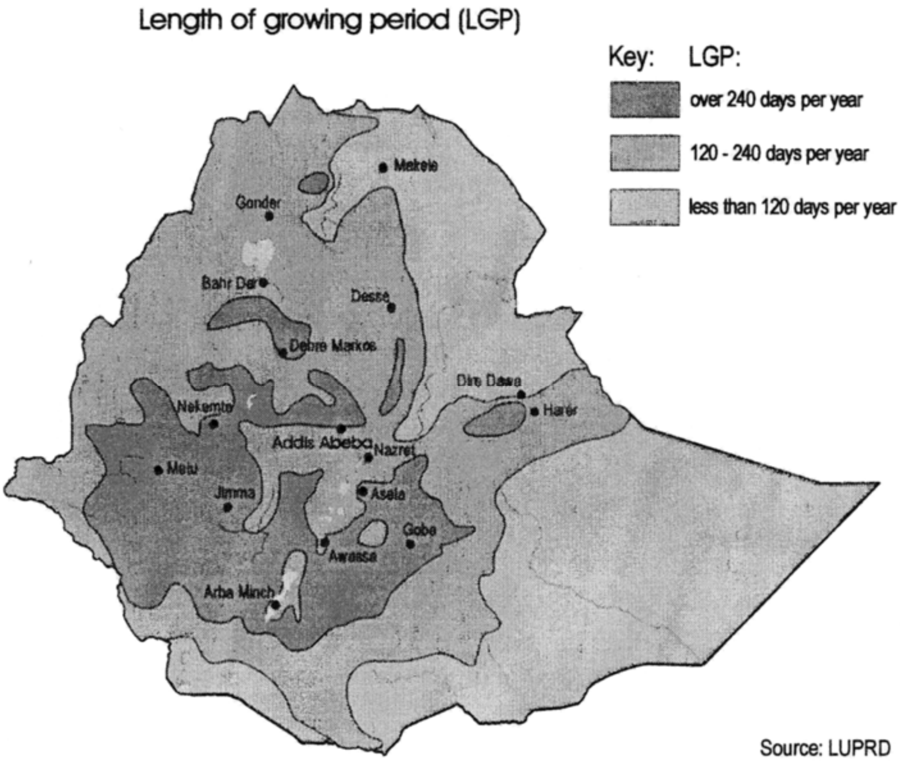

Figure 10. Length of growing period map for Ethiopia (three categories only)

TABLE 3
Area coverage for each agroecological belt in Ethiopia, subdivided in different LGP zones in each belt (see Fig. 10).

	Area of Length of Growing Period (LGP)			
Agroecological Belts [1000qkm]	**dry (<120 days)**	**moist (120-240 days)**	**wet (>240 days)**	***Sum***
I (Wurch)	0,00	0,41	2,44	*2,85*
II (High Dega)	0,00	2,95	4,95	*7,89*
III (Dega)	2,24	23,46	19,77	*45,47*
IV (Weyna Dega)	11,26	171,44	159,41	*342,11*
V (Kolla)	26,54	135,91	22,02	*184,47*
VI (Berha)	409,66	121,83	10,01	*541,50*
Lakes				*8,79*
Sum	***449,69***	***456,00***	***218,61***	***1133,09***

Note: Due to the generalised LGP map base (EMA 1:2 million), inaccurate zones may result, particularly the "dry" Dega, "wet" Kolla and "wet" Berha agroecological zones. The "moist" Berha, however, basically describes Gambela area in western Ethiopia, where seasons are either hot and dry, or hot and inundated, hence unsuitable for rainfed agriculture.

mountains, this 'High Dega' Belt, where only barley and potatoes can be grown, extends further down than in the northern part of the country. For example, this barley belt is persistent above 3,000 m in the south. Towards the north, however, the 'Dega' proper belt extents higher up, to about 3,400 m a.s.l., and the 'High Dega' barley belt can be found as high up as 3,800 m a.s.l.. This asymmetry can be explained by less clouding and thus higher daily maximum temperatures in the northern parts of the country. Climatic observations will have to confirm this empirical field observation, however.

All in all it should be noted that a majority of the Ethiopian people live in the parts of Ethiopia coloured green, namely an area of approximately 400,000 km2, roughly 44 Million land users. This gives an average density of population in the suitable agroecological altitudinal zones of 110 persons per km2. This density is about a factor 10 higher than for other areas in the Sahel belt where only about 10 persons per km2 live. Climatic variability in the Weyna Dega and Dega Belts of Ethiopia will therefore affect many more people than in other parts of the Sahel region. This is of primary importance when assessing the vulnerability to drought and eventual famines in Ethiopia. Table 3 gives an overview of the area in each AB, as well as the three major LGP zoning categories in each belt. One should notice, however, that the data source used by the LGP map has a very approximate scale, and is not really to present standards.

4.2 A brief evaluation of the maps

There are clear strengths in the presently published Agroecological Belts Map of Ethiopia. The first and foremost is its precise topography, with 200 m contour lines which allows an extremely precise geo-reference for all further information at that scale. There is also an opportunity to down-scale information, or to overlay the present topography over modern satellite imagery, resulting in a very high precision and applicability for various purposes.

A second major strength of the map is that the thermal regime of Ethiopia, as derived from observations of the actual farming systems, is realistic for present-day climatic conditions. Upper limits of a number of actually cultivated crops were determined along transects and characterised for most parts of the highlands. Future agroecological zoning and sub-zoning will thus have a good reference of major boundaries of such crops at the time of field work.

A third strength of the map is that major moisture regimes could be determined using field observations of major crops, such as sorghum which is particularly useful to determine drought conditions. Wherever farmers grow sorghum, there must be sufficient rainfall for at least one cropping season, and this was mapped. The Kolla Belt thus gives a fairly good overview of the distribution of dry and of warm to hot areas where rainfed farming is still possible and thus moisture is available during a rainy season. However, due to variability in rainfall, these zones are less reliable than the upper belts defined by thermal boundaries.

A fourth major strength of the map is that certain remote areas have been included in the field observations where no scientific assessment had been made before. For example, in northern Ethiopia the Tekeze intra-montane valley has been studied in detail, and included in the models, so that even areas not accessible by car have been empirically studied in detail.

There are, however, certain weaknesses of the maps which should not be overlooked. One weakness is that the road network and the location of villages had to be taken from other map sources of EMA, and it must be realised that road conditions have not always been updated. Particularly in areas not recently visited by field transects, the status and delimitation of roads may be erroneous. A sound analysis using global positioning systems (GPS) would be the best approach to improve such networks. However, for the present map this could not be done. A further weakness is that areas not visited, particularly at lower altitudes along the borders of Ethiopia, may not be as precisely modelled as areas where transect observations were carried out (cf. Figure 7 and Table 1). A further weakness may thus be possible in errors in the classification of agroecological zones in these areas.

One should, however, also evaluate the opportunities which can be derived from the present maps. For example, it would be easy to subdivide the present MAZ for specific purposes. If new crops are developed with specific conditions similar to some traditional crops, this could easily be modelled and applied by GIS. A differentiation is possible even in altitude, for example for subdividing the Weyna Dega Belt into other sub-zones or sub-belts. A detailed assessment of the climatic information, as was done by Mengistu et al in 1989, could be applied to the present DEM.

There are many other applications which could be made from the map. For example, possible applications include:

- Visual use: composite maps (for offices), showing an overview of the country, primary agricultural areas, high mountain tops, precise topography
- Modelling: Population distribution (statistics), land use and cover classification, land use potentials, SWC potentials (strategies, options, constraints); generalised crop potentials, forestry potentials, soil erosion hazards and conservation potentials, soil fertility strategic planning.
- Planning: watershed classification and delimitation, strategic road planning, fertiliser distribution planning.
- Digital applications: application in combination with satellite imagery (case studies).

There are certain threats which could be emerging when misusing the maps. For example, one should not overestimate the potential of the map for direct application. There are locally specific agroecological parameters which are equally important for agroecological assessment, but have not been included in the present map. These are: soil status, soil fertility, soil water conservation, plant diseases and pests, the remoteness of the area, the raggedness of the topography, or available markets for agricultural development. Of course, parameters such as soil status and soil types could be easily over-laid in the GIS application once such layers are available at sufficient precision. The published maps of the LUPRD, unfortunately, do not allow a sufficient differentiation of occurrence of soil types and other parameters in many instances.

One should also not forget that besides the agroecological potential there are further needs to be looked at. For example, bio-diversity, both of cultivated species and natural plants and animals, should be included in any agricultural development planning. The present map does not give a basis for biodiversity differentiation, as for example no natural vegetation areas are shown. Other map projects are much more detailed in this respect. Besides cropping and major agricultural crops used to determine altitudinal zones, there are other needs of the farming systems which should be included. For example, livestock densities, availability of grazing grounds, or the available woody biomass, are important components of each farming system in Ethiopia and should thus be included. Others, such as cash crops like coffee, tea or chat, banana or citrus fruits, would need a specific agroecological zoning which can not be directly derived from the map. Here again, once parameters are known, it would be fairly easy to determine the suitability for such specific crops using the present layers of information combined with others, such as the agroclimatic requirement.

5. CONCLUSION

Three major conclusions can be drawn from the production of the present agroecological belt maps.

1. The first and foremost information base, namely a sound and precise topographical elevation model for the whole of the country, should be considered a major achievement of the map. On top of this, there is systematic information in the form of generalised agro-ecological information, classified as agroecological belts (ABs) denominating major agro-ecological zones (MAZ). This additional information gives, at a glance, a very comprehensive overview of the country as a whole, and can also be used when travelling along the road to determine at which elevation and zone one is currently observing certain features. Researchers as well as technicians, practitioners and travellers can make use of this information when assessing locally specific parameters. The topographic base map, finally, is precise enough to guide even those travellers who may not want to follow major roads, but intend to cross Ethiopia on foot. One should not forget, however, that one single centimetre represents a distance of at least 10 kilometres in the landscape. The topographic features, therefore, are rather general, but still highly precise.
2. Although 8,000 copies have been produced of the three map sheets and made available in Ethiopia, one should not forget that an even better source of information for planning and other purposes is the geographical information base available at the Soil Conservation Research Programme of the Ministry of Agriculture, and at CDE in Berne. This information can easily be adapted according to specific requirements, new models in agroecology, or any other applications of processes and observations from the field and for the field.
3. A major opportunity of the current map and GIS is that any window for specific sub-regions can be opened, and information downscaled from 1:1 million to scales of about 100,000. Below that, it will be difficult to use the 200 meter contours and models, for example when overlaying with aerial photography. Hence, a best application scale is about 1:500,000. For this scale, the map provides a most realistic basis.

It is expected that the agroecological belts map will serve its purpose not only as a composite map, hopefully in many offices throughout Ethiopia, but also as set of three individual maps which can be used when travelling through Ethiopia, when assessing certain rural areas, or when doing regional or national planning. It certainly supplements other products with an enhanced topographical base and access to GIS and other information systems.

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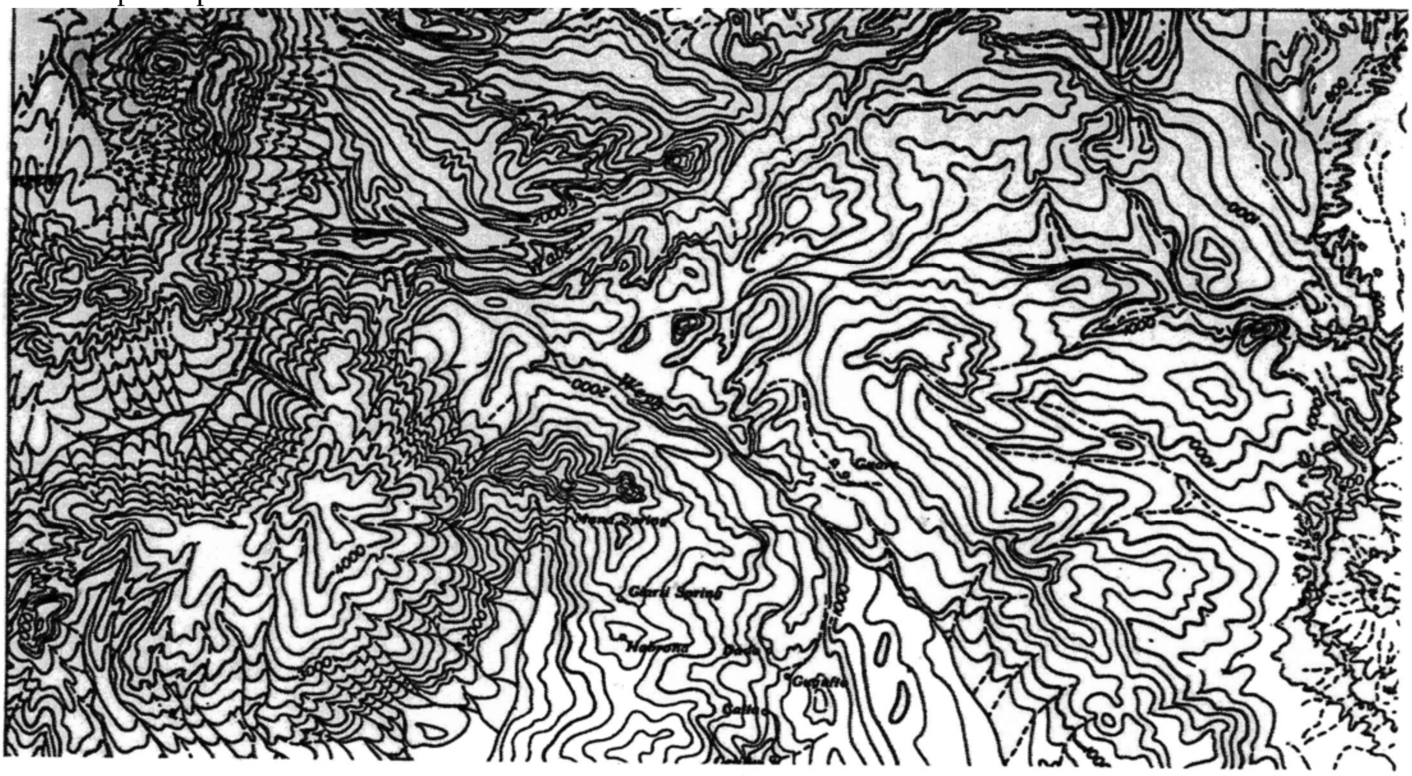
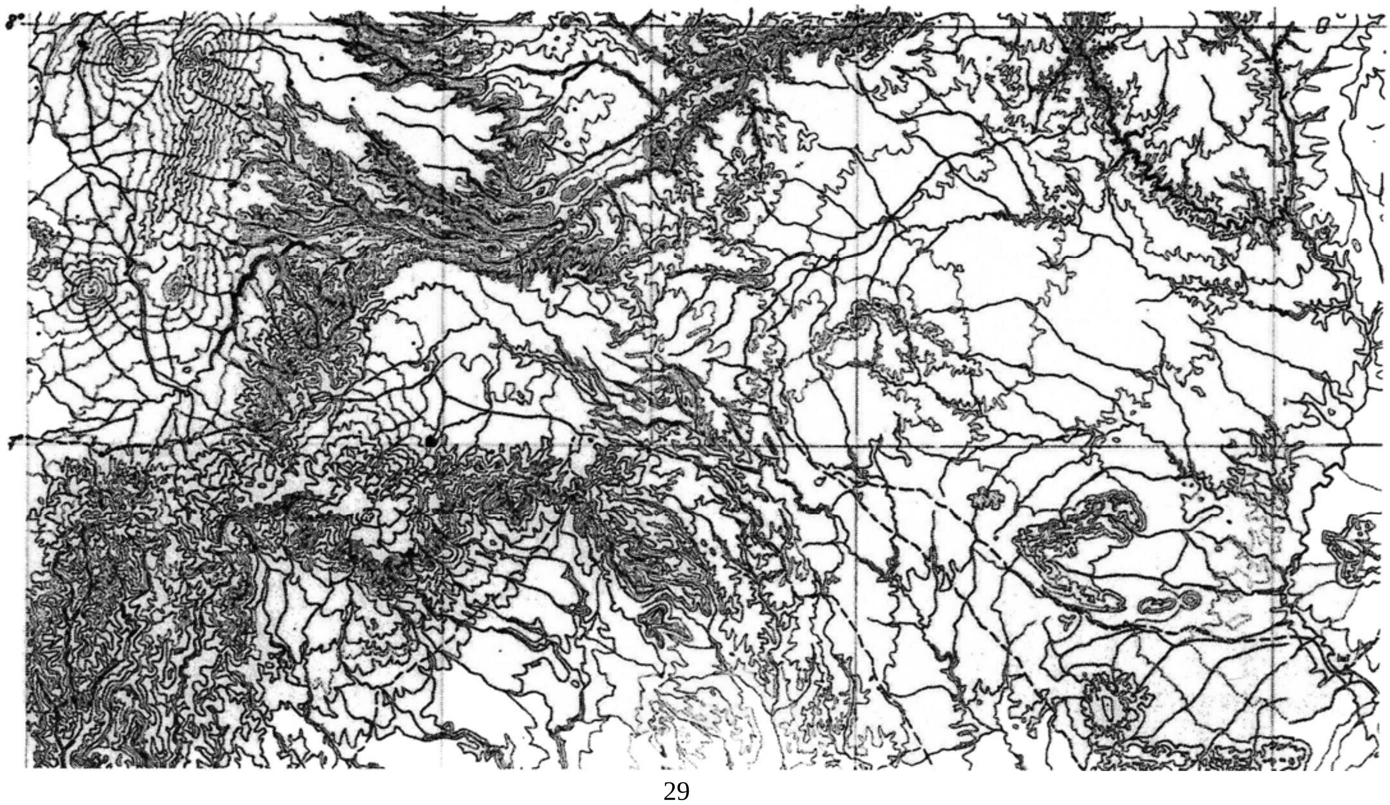
ANNEX I: Comparison of topographic bases of (1) map by EMA (1:2 million) with (2) present maps of Agroecological Belts (1:1 million)

Comparison of a similar area of Ethiopia (Upper Wabe Shebelle area in Bale) between the currently used EMA map (top) with the map base for the AB map (bottom) at similar scales (1:2,000,000) using 200 m contour lines and rivers. Note the relative inaccuracy of the top map compared to the bottom one.

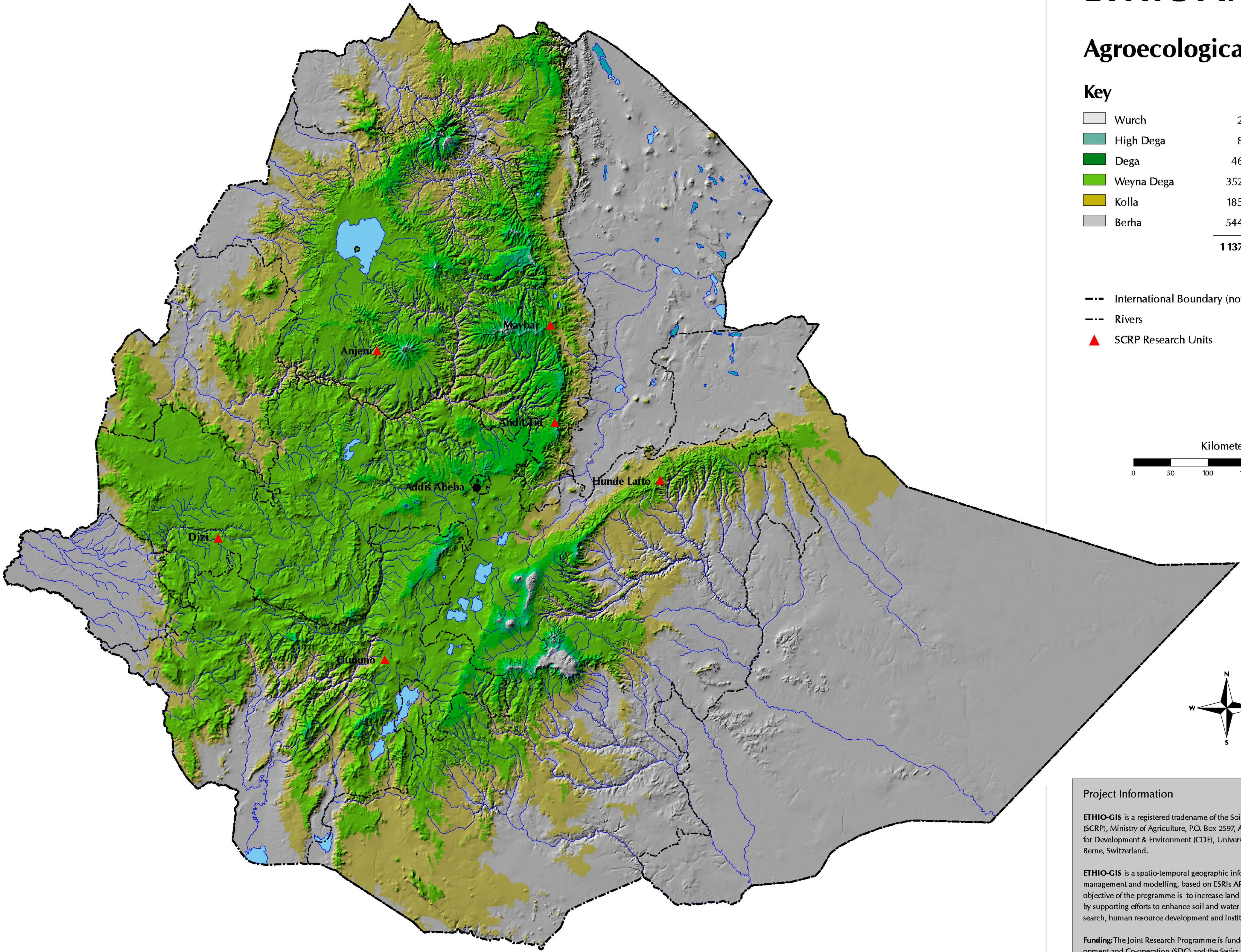




ANNEX II: Agroecological Belt Map (1:5 million)

ETHIOPIA

Agroecological Belts



Key	Area	
Wurch	2 000 sq. km	0.2 %
High Dega	8 000 sq. km	0.7 %
Dega	46 000 sq. km	4.0 %
Weyna Dega	352 000 sq. km	31.0 %
Kolla	185 000 sq. km	16.3 %
Berha	544 000 sq. km	47.8 %
	1 137 000 sq. km	**100 %**

International Boundary (not authoritative)

Rivers

SCRP Research Units

Project Information

ETHIO-GIS is a registered tradename of the Soil Conservation Research Programme (SCRP), Ministry of Agriculture, P.O. Box 2597, Addis Abeba, Ethiopia, and the Centre for Development & Environment (CDE), University of Berne, Hallerstrasse 12, 3012 Berne, Switzerland.

ETHIO-GIS is a spatio-temporal geographic information system for natural resource management and modelling, based on ESRIs ARC/INFO (UNIX & NT). The general objective of the programme is to increase land productivity in a sustainable manner by supporting efforts to enhance soil and water conservation in Ethiopia through research, human resource development and institution building.

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Sources: DTM based on Series 1:250,000 of the Ethiopian Mapping Authority.