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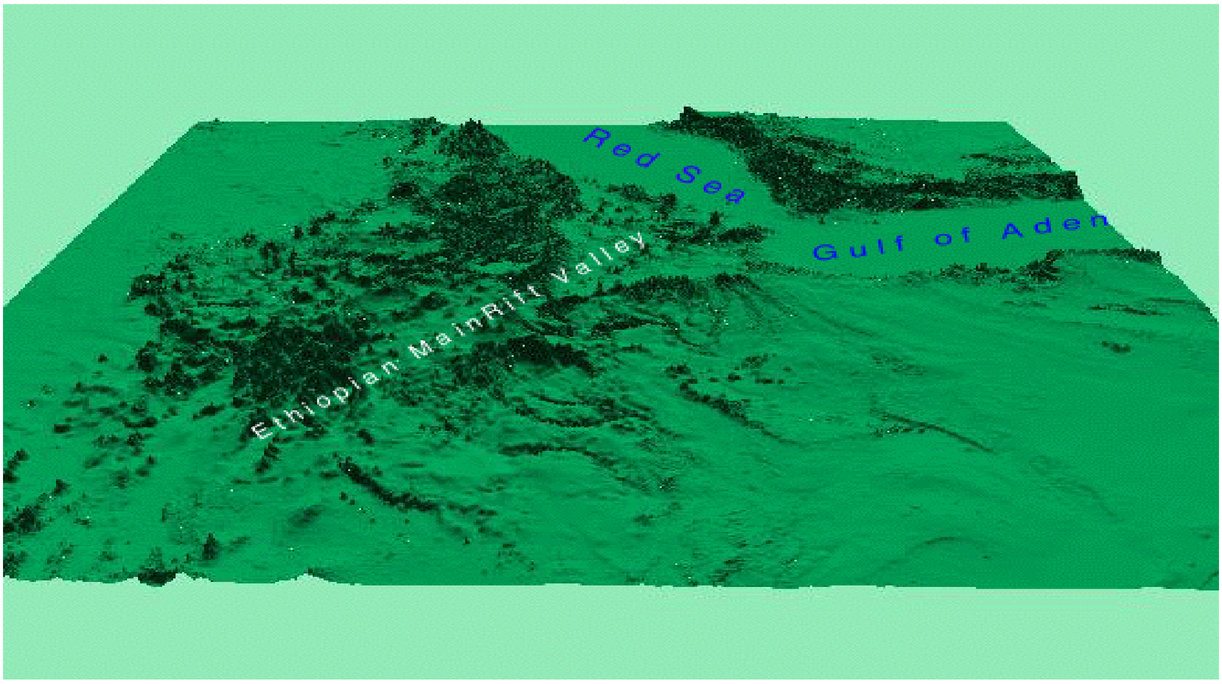
Integrated Application of the GIS and Remote Sensing in Solving Hydrogeological and Environmental Problems in the Central Part of Ethiopia and its Possible Extensive Future Use

(Auszug / Extract)

von Mezemir Fikre-Mariam Wagaw



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Integrated Application of the Geographic Information System and Remote Sensing in Solving Hydrogeological and Environmental Problems in the Central Part of Ethiopia and its Possible Extensive Future Use

vorgelegt von

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Titelseite: 3D-view of North-East Africa - based on the e20n40 tile of the USGS

OBSERVATION POSITION:

X = 671936 m.	Y= -711611m	AGL = ASL = 92316m
FOV = 50	pitch = -30	azimuth = roll = 0
sun-azimuth = 9°	sun-elevation = 59°	sun-ambience = 0.50
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To my brave twins,

Etsubdenk & Genet Fikre-Mariam.

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Berlin – December 2002 Mezemir Fikre-Mariam

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List of Acronyms

CCT	Computer Compatible Tape
CD-ROM	Compact Disk Read Only Memory
E, W, N, and S	East, West, North, and South (Compass direction)
ERDAS	Earth Resource Data Analysis System
ERE	Effective Resolution Element
FFT	Fast Fourier Transformation
FOV	Field of View
GIS	Geographic Information System
GUI	Graphical User Interface
IFFT	Inverse Fast Fourier Transformation
IFOV	Instantaneous Field of View
IHS	Intensity Hue Saturation
IPC	Inverse Principal Component Analysis
IR	Infra Red
N1a	Alaji basalts of early Miocene, (which forms the main trap basalt)
N2r	Old alkaline and per alkaline rhyolite domes and flows of early Pliocene
N2Qb	Bofa basalts of Pliocene
NNE	north-north-east (Compass direction)
NNW	north-north-east-west (Compass direction)
PC	Principal Component Analysis
Qwra	Alkali and per alkali rhyolites, trachytes, domes and flows of basalt of Pleistocene
RAM	Random Access Memory
RGB	Red Green Blue
TIN	Triangular Irregular Network
TCO	Total Cost of Ownership
TOP	Target (Task) Oriented Project
USGS	United States Geological Surveys
VLF	Very Low Frequency
WWS	West, West South (Compass direction)

Key words: GIS, remote sensing, information infrastructure, lineament, groundwater, environment architecture

Abstract

This research is conducted with the aim of studying the structural setup, geology and hydrogeology of the western escarpment of the main Ethiopian rift valley by using remote sensing data and GIS technology and its possible use for the dwellers of the area. A Landsat TM, MSS, SPOT panchromatic image, different topographic maps of 1:50000 scale as well as analog historical aerial photos of selected areas were used for the study. These data were processed and integrated into a single GIS database. The meteorological data from the three different stations were also processed and compiled to the database. The input and integration of all available results to a single reliable and robust database created a virtually new way for studying and analyzing a multitude of overlays and their combination.

The analysis had demonstrated that remote sensing and GIS technologies are relevant and vital instruments in mapping the main lineaments as well as better understanding of the ground water availability. Results about the village distribution, geomorphology and the continuous natural forest diminishing were also obtained. Further, it was shown that in this climate zone, the search and exploitation of groundwater should not be considered as an independent work and as a closed entity in itself. It should rather be the integral part of an overall balanced environmental management and social development of the area.

The viability of using remote sensing as a fast, timely and reliable information source was discussed. The benefit and usefulness of introducing the GIS as an interdisciplinary collective tool for tackling the diverse needs and problems was articulated in detail and further study was recommended.

Schlüsselwörter: GIS, Fernerkundung, Informationsinfrastruktur, tektonische Störungslinien, Grundwasser, Umwelt Architektur

Kurzfassung

Die vorliegende Arbeit hat die Zielsetzung, den strukturellen Aufbau und die Hydrogeologie des westlichen Steilhanges (escarpment) sowie das äthiopische Hauptgrabensystem auf der Grundlage digitaler Satellitenbilder und unter Anwendung der GIS-Technologie zu untersuchen und deren Nutzungsmöglichkeit für die Bewohner zu erkunden. Dafür wurden die Landsat TM, MSS sowie die SPOT-panchromatischen digitalen Daten, topographische Karten 1:50000 und historische analoge Luftbilder für kleinere ausgewählte Gebiete verwendet. Diese Daten wurden erfasst, digital bearbeitet, georeferenziert und in eine einheitliche GIS-Datenbank integriert. Die so erstellte einheitliche Datenbank ermöglichte unterschiedliche neue Wege der Betrachtung und Analyse in verschiedensten Kombinationsformen und Überlagerungen. Die meteorologischen Daten von drei verschiedenen Stationen wurden ausgewertet.

Diese Arbeit hat gezeigt, dass Fernerkundungs- und GIS-Technologien wichtige Mittel für die Kartierung der tektonischen Liniamente sind sowie besseres Verständnis des geologischen Aufbaues und der Verfügbarkeit des Untergrundwassers ermöglichen. Es wurden auch Ergebnisse über die Siedlungsstruktur, die Geomorphologie und den Forstbestandsschwund erzielt. Außerdem sollte in dieser Klimazone die Suche und Nutzung des Grundwasser-Vorkommens nicht als eine in sich geschlossene und unabhängige Arbeit gesehen werden, sondern vielmehr als ein integraler Teil der gesamten Umweltplanung und der ausgeglichenen Entwicklung des Gebietes.

Die Vorteile der Nutzung von Fernerkundungsdaten als eine schnelle flexible Datenquelle wurden erörtert. Die Vorzüge und die Notwendigkeit der GIS- Einführung als ein gemeinsames Informationsverarbeitungs- und Verwaltungssystem für verschiedene Fachdisziplinen und Aufgabenstellungen wurden dargestellt und darüber hinaus Lösungswege für weitere Untersuchungen vorgeschlagen.

Summary

Sufficient surface/ground water availability is one of the crucial factors for a healthy future socio-economic development in the study area. Hence, as a contribution towards a better understanding of the structural/hydro geological setup of the area, this study uses remote sensing data, and applies GIS databases and tools. Specifically, the study assesses the geologic/geomorphologic setup of the area, the alignment of fissures, faults and their formation in the region.

For this study, digital images of the Landsat TM, MSS and SPOT panchromatic were used. Additionally, analog historical aerial photographs of a smaller area as well as topographic map of 1:50000 scale were available.

For the digital image processing, the creation and analysis of the GIS database, the programs Erdas Imagine and ARC/INFO were implemented. The main research aims were to study:

- the construct and composition of the upper (shallow) geology,
- the tectonical structure and its distribution pattern in the region,
- the underground water circulation,
- the dwelling pattern, geomorphology, surface water, and their interaction,
- the discovery of the above geology and its potential utilization by the villages in the respective adjacent areas as well as
- commenting the suitability of remote sensing and GIS for similar problem settings.

A detailed study on the lineament pattern was carried out. In this study the tectonic lineament of the NE-SW was found to be the predominant one, followed by the semi perpendicular NW-SE direction. Next to that, the population distribution in the area was studied. Here, it was easily revealed that the great majority of the villages are settled on the tops and sides of the volcanic cones and the top of the horst formations. The distribution of the villages in the study area is seen to be uniform with a higher concentration around the towns and irrespective of the climate regime.

After that rivers, wadies and wetland areas were mapped. With the help of the GIS technology various analyses were carried out, and the interactions among these quantities were commented and discussed. Further, the village distribution pattern, the water availability and the natural vegetation were brought in relation to the slope and aspect of the area. Streams, rivers, wetlands, and the forest distribution were overlaid and studied. Their interdependency was analyzed, interpreted and discussed.

The forest and village distribution maps were overlaid and compiled. The steadily diminishing size of the forest, which is mainly caused by the high demand of fire and construction wood is presented and articulated. Unfortunately, against this alarming devastation of the native forest, there is still no meaningful re-foresting program in place.

For parts of the study area, the digital satellite image processing is shown to be a vital supplementary information source to those already existing geological/ hydro geological maps. This has resulted in a considerable information gain.

From the study, the following conclusion were derived:

- especially in the escarpment area, but also in the rift valley region to a lesser extent, there are substantial parallel tectonic lineaments which are mainly northeast - southwest directed,
- there are also second group of lineaments, with lesser intensity, in the NW-SE direction,
- the lineament length varies from few kilometers to 50 km or more, and
- it is also observed that the overwhelming majority of the villages are located on the tops and sides of horst formations and volcanic eruption centers.

The existence of such tectonic structure may create a favorable condition for ground water circulation in the region. The lineament structures and the weak zones can potentially be used as an underground reservoir. The effective use of such structures may increase water quality and decrease the loss of water in form of evaporation. In this regard future additional high resolution study is vital.

The locations with high rainfall intensity, mainly the escarpment areas, are at the same time areas of extensive agriculture, causing a concurring interest for the same locality with the new-water building and surface water catchments. In order to avoid any negative environmental impact, the extensive agricultural use should be brought in harmony with the water protection and environmental preservation locations.

Based on the results, an integrated approach to the surface/groundwater as a single entity is recommended. The approach of building “many small” dams more frequently upstream at the valleys - on the escarpments is more preferable. This causes the deceleration of the erosion, and less evaporation. The availability of water for villages around these high land localities will be secured, the villages in the lowland area and in the rift valley can get clean water in a form of ground water in their vicinity. In such a method, the risk of mineralization on the rift floor could also be confined. Besides this, a wide possibility may be opened for the construction of several “decentral and small” hydroelectric power-stations for local consumption.

An additional aim of the study was to see how effective the used remote sensing and GIS technologies for hydro geological and environmental problem settings could be. Here the remote sensing is proved to be a fast and flexible data source. The GIS is also found to be an effective geographic (including the respective trailer attribute) data management and analysis tool.

Some methodical approaches were discussed on how to tackle the effects of cumulative impact on the environment in Ethiopia. In this respect the collective approach of GIS-introduction and its consecutive collective implementation in Ethiopia was seen in depth. The proper introduction and utilization of GIS and related technologies can serve as an information infrastructure tool, and this may decisively contribute to the development of the country and can be a great help for the government’s declared “sustainable development and poverty reduction” program which is underway in the recent years. Towards this end, an integrated multi-user introduction of GIS platform for the different specialists and users was discussed and recommended.

Zusammenfassung

Eine ausreichende Qualität und Menge an Oberflächen- bzw. Grundwasser ist einer der Hauptbausteine für eine anhaltende und gesunde gesellschaftliche Entwicklung des Untersuchungsgebietes. Deshalb setzt diese Arbeit die Geofernerkundung und das GIS-Verfahren ein, um einen Beitrag zum besseren Verständnis der strukturellen und hydrogeologischen Gegebenheiten und Gesetzmäßigkeiten des Untersuchungsgebietes zu leisten.

Die digitalen Bilddaten der Landsat TM und MSS sowie der panchromatischen SPOT-Aufnahmen wurden dazu verwendet. Als Referenzbasis diente die topographische Karte 1:50000. Für eine gezielte Spezialuntersuchung wurden historische analoge Luftbilder herangezogen. Für die digitale Bildbearbeitung, die Erstellung der GIS Datenbank sowie der späteren Analyse wurden die Programme Erdas Imagine und ARC/INFO verwendet. Im Mittelpunkt der Untersuchung standen:

- der Aufbau und die Zusammensetzung des Untergrundes,
- die tektonische Struktur und deren Verteilungsmuster in der Region,
- die Untergrundwasserzirkulation, deren Erschließung und Nutzungsmöglichkeit für die angrenzenden Dörfer,
- die Siedlungsstruktur, Geomorphologie, Oberflächengewässer und deren Wechselwirkung sowie
- die Tauglichkeit von Fernerkundung und GIS für solche umweltbezogene Aufgabestellungen.

Zunächst wurden die NO-SW gerichteten tektonischen Lineamente, die im Untersuchungsgebiet am häufigsten auftreten, sowie die weit weniger vorkommenden NW-SE gerichteten Lineamente eingehend analysiert. In einem zweiten Schritt wurde die Bevölkerungsverteilung im Untersuchungsgebiet analysiert. Dabei konnte festgestellt werden, dass der größere Teil der Dörfer auf den Vulkankegeln und entlang der Horstbildungen in den Steilhangs-Gebieten angesiedelt ist. Die Dorfverteilung im Untersuchungsgebiet ist, mit etwas größerer Dichte in der Nähe der Kleinstadtsiedlungen und ungeachtet der klimatischen Zone, weitestgehend einheitlich.

Danach erfolgte die Kartierung der Flüsse, Wadis, und anderer Feuchtgebiete. Mit Hilfe von GIS Methoden wurden umfangreiche Analysen vorgenommen und die jeweiligen Wechselwirkungen aufgezeigt und erörtert. Die Größen wie Hangrichtung (aspect) und Hangneigungswinkel (slope) wurden aus den digitalisierten Höhenlinien erstellt und in Verbindung mit der Verteilung der Dörfer, der Vegetationsstruktur und dem Gewässernetz diskutiert.

Wald- und Dorfverteilungskarten wurden überlagert und verglichen. Es wurde auch der Forstbestandsschwund - der überwiegend durch den sehr hohen Brenn- und Bauholzbedarf verursacht ist - dargestellt und problematisiert, wogegen es bis jetzt keine nennenswerte Wiederaufforstungsaktivität gibt.

Für einen Teil des Untersuchungsgebietes wurde aufgezeigt, dass der Satellitenbild-Auswertung ergänzend zu den vorhandenen geologischen und hydrogeologischen Karten eine erhebliche Bedeutung für die Informationsgewinnung zukommt.

Aus dieser Arbeit können folgende Schlussfolgerungen gezogen werden:

- besonders in den Steilhangbereichen - in dem Grabensystem in geringerer Intensität - sind die NO-SW gerichteten tektonische Lineamente gut ausgebildet und ausgeprägt,
- es ist auch eine zweite Lineamentenrichtung, die NW-SE gerichtet ist, festzustellen,
- die Länge dieser Lineamente reicht von einigen Kilometern bis 50 km oder mehr, und
- die meisten Dörfer sind auf den Höhen und Seiten der Horstformationen und auf den Hängen von den jetzt passiven Vulkanausbruchszentren lokalisiert.

Die Existenz solcher tektonischer Strukturen kann eine sehr gute Bedingung für die Grundwasserleitung und -speicherung schaffen. Diese Strukturen können als Wasserspeicher gezielt genutzt werden. Damit könnten hohe Wasserqualität und geringere Verdunstungsverluste erreicht werden. Detailuntersuchungen in dieser Richtung sind angebracht.

Das Steilhanggebiet ist das Gebiet mit ergiebigen Niederschlägen, aber zugleich ein Gebiet der extensiven Landwirtschaft. Um die wahrscheinlichen Konflikte der Landnutzung-interessen zu vermeiden, sollte die landwirtschaftliche Tätigkeit im Einklang mit der Schutzgebietsbildung gebracht werden.

Ausgehend von den oben geschilderten Tatsachen ist eine Gesamtbetrachtung der Oberflächen- und Untergrundgewässernutzung zu empfehlen. Die Möglichkeit der Bildung von „vielen“ Ministaudämmen in den oberen Talbereichen der Steilhänge ist im allgemeinen zu bevorzugen. Dieses wird die Erosion der landwirtschaftlichen Nutzflächen verlangsamen, den möglichen Verlust durch Evaporation verringern, die Verfügbarkeit des Wassers für die Einwohner der höheren Lagen sichern und durch die natürlichen Grundwasserzirkulations-prozesse ein sauberes Grundwasser für die Dörfer der tieferen Gebiete sichern. So eine Gesamtlösung würde zudem die Gefahr der Mineralisation der Dämme in den tieferen Gebieten weitestgehend minimieren. Außerdem ist die Möglichkeit für den Aufbau von „dezentralen kleinen“ Wasserkraftwerken, die den lokalen Energiebedarf decken können, dadurch gegeben.

Ein weiteres Ziel der Arbeit galt der Prüfung der verwendeten Fernerkundungs- und GIS-Verfahren für die hydrogeologischen und umweltbezogenen Fragestellungen. Dabei konnte die Eignung von Fernerkundungsmethoden als schnelle und flexible Datenquelle nachgewiesen werden. Die Tauglichkeit von Geofernerkundungs- und GIS-Verfahren für hydrogeologische und umwelt bezogene Problemstellungen wurde eingehend diskutiert.

Es wurden verschiedene methodische Ansätze vorgeschlagen, wie die negativen kumulativen Wirkungen - die in dieser Arbeit thematisiert wurden - aufgefangen und schrittweise gelöst werden können. Die erfolgreiche Einführung und Anwendung von GIS und in deren Zusammenhang stehenden Technologien können einen entscheidenden Beitrag für die Entwicklung des Landes leisten und die effektive Bildung einer Informationsinfrastruktur ermöglichen. Für das, von der äthiopischen Regierung seit kurzem ins Leben gerufene „poverty reduction“ Programm kann so ein System wichtige Grundlage bilden. In dieser Hinsicht wurde die integrierte Mehrnutzereinführung von GIS-Plattformen für Interessenten aus verschiedenen Bereichen erörtert und vorgeschlagen.

Problem Overview and Objectives of the Research

Ethiopia with its peculiar highly undulating and tilted geomorphology poses a serious challenge in securing enough water to its people and in executing medium to large scale economic developmental undertakings. In the last several decades, it is observed that different region of the country is struck by “major cyclic” drought repeatedly. This cyclic recurrence of "irregular rainfall" necessitates, to search for and develop a long-term solution which should address the potential scarcity of surface and ground water.

It is a well established fact that more than 85% of the Ethiopian population live in the countryside and is predominantly engaged in mixed cattle breeding and crop farming, which directly depends on the natural rain distribution and intensity. As a drinking water source, in the most traditional way, people use springs. Where this is not available, hand-dug wells and rivers are the main sources. In the rural areas, especially in the highland areas, the increased use of highly steep slope locations for plowing and as a grazing field is widely observed, which otherwise would have served as a new water building zone. This has led to a rapid deforestation and higher run-off of the surface water to the lower elevation. There is as a result often less free space, less wetland and drinking water entry area and a very limited amount of natural forest. Natural forest with its bio-diversity, except the few commercial eucalyptus tree patches, is becoming steadily scarce. The irregularity of the rainfall, increased necessity of water security for drinking, cattle, and other agricultural activities - together with the substantial population growth - require water conservation, protection and management policy at the federal and local governmental levels. The recurrent drought in all climate zones of Ethiopia forces the eventual creation of a mechanism for protection of catchments, main streams as well as locations with a very high inclination slope.

In general, the “normal” climate nature of the study area shows a prolonged dry season followed by an intense rain over a two to four month period.

The water balance problem of the area can be stated as:

i. intense rain occurs mainly in the highland areas, and to a lesser extent in lowland areas for short periods, separated in both cases by a long dry spell. The relatively short and intense storm and flood periods are within a couple of weeks over and much water tends to pass quickly out of the area,

ii. heavy concentration of runoff causes major erosion and soil degradation problems in the highland areas and at the same time the sediment transported, often with a very high speed downwards to the lowland areas, will cause major damage of cultivated land and siltation of dams,

iii. the continuing population growth and the economic activities in the rural and urban areas has considerably increased the need of water for drinking, agricultural and industrial purposes, and

iv. the periodic rain time “irregularity” in almost all parts of the country, and the tremendous social and economic disorder for millions of citizens as a direct consequence of this.

The aforementioned water cycle and the potential water shortage are crucial issues for the entire society, independent of their social structure. This problem should be encountered with an accelerated strategic approach to tackle the water, energy and environment management as a single entity. For this the proper understanding of the environment architecture – which should comprise the geology/geomorphology, native natural flora and fauna, climate regime and meteorology of a given local region - as a single entity is decisive. Effective solution of this problem demands an interdisciplinary approach from several sides of natural and social science disciplines. It requires also a substantial amount of data and information. The proper and effective management of environmental data, information and their proper access by the individual field specialists, interested governmental and non-governmental institutions, and individual end users will - in the future - determine the wellbeing and progress of the society in this climatic zone.

Often at different levels of government - decisions on capital investment and resource development for water and environmental management at large - are made in an atmosphere of greater or lesser uncertainty and with value judgments strongly conditioned by weaker information base. As a result, several development projects will have the fate of unexpected and often undesirable outcomes. As a result they are economically, socially, and environmentally unacceptable. The ever increasing demands on the natural resource needs wise and prudent management of the natural resources and the environment. Such management needs are best served if accurate, on time, and consistent resource inventories are made available to the resource manager - and any decision maker for that matter - at suitably frequent intervals, and with regular updates.

Although the identification, measurement, and inventory of our environment resource is a complex task, the technology of remote sensing, digital image processing and Geographic Information System (GIS) does offer the potential to produce a broadly consistent data base at a spatial, spectral, and temporal resolution, which is useful for a competent management. The coupling of remote sensing with GIS may basically change our methods and models of data analysis, as well as our perception of the environment and the society. The GIS allows us a very high data integrity, actualization capability, and high-grade data management and analysis facility. It allows us an “unlimited” scalability and data integrity. This leads each development task to a well coordinated Target (Task) Oriented Project (TOP), from planning, project execution and final documentation to a far later operational control of any realized and completed environmental/social project. It can permit good performance in planning, execution, documentation and the fostering of various environmental resource works in general and water supply, construction and maintenance in particular. It may also secure a transparent background information for post-construction operational management and optimal use of erected structures, which will be a distinct advantage of the GIS technology against the recent practices.

For this study remote sensing and other ancillary data were made available. Digital image processing and GIS technologies have been used. As a final result, a GIS database with more than 5 GB data size was built and maps are generated and discussed.

A Methodical Approach to the Introduction of GIS to Ethiopia

In the past chapters the application of remote sensing and GIS technology as a combined tool for the surface and ground water study in particular and an environmental study, in the broader sense, had been discussed. The next difficult task is the introduction of this technology to Ethiopia under the condition of scarce financial resource and trained man power.

In this chapter, a condensed literature review is done on the recent development challenges of the country and on ways of GIS implementation strategy. At the end of the chapter a proposal will be made on the possibility of price effective and optimal introduction of GIS to Ethiopia. The multi-participant approach is found to be best fitting as will be elaborated below.

Administrative Institutions and Potential Users of GIS in Ethiopia

In Ethiopia there are various governmental institutions, private agencies and Non Governmental Organizations (NGOs), which may potentially use this opportunity. The recent political power and administrative mechanism in Ethiopia is realized by the federal and regional governments at the higher level, woreda and kebele administrative units at the lower level of the hierarchy. This inherits different management and responsibility levels in any decision-making, planning, realization and quality control processes and procedures.

In October 2001, the Ethiopian government had announced new additional ministries that may help bring more efficiency and better work coordination. Among the new ones are ministries of rural development, capacity building, infrastructure, federal affairs and revenue with each of them having legal jurisdiction to coordinate the activities of related public offices. For instance the ministry of education, science and technology commission, civil service commission, Ethiopian management institute, Ethiopian civil service college and justice and legal research institute will be accountable to the ministry of capacity building, see //www.ethiopianreporter.com/eng_newspaper/Htm/No267/r267new2.htm.

The large scale introduction and implementation of GIS to the country may be better facilitated, due to the existence of these new conglomerate federal offices.

The Ethiopian Government Recent Sustainable Development Program and the Potential Role of Geographic Information System in its Realization

In the recently revised working document of over 200 pages[i], the government has clearly stated its intention and framework plan for the fiscal years 2002/2003 through 2004/2005.

The major and broad thrust of the strategy during the program's execution period are stated as[ii]:

- overriding and intentional focus on agriculture as the sector is the source of livelihood for 85% of the population where the bulk of the poor live. The government gives overriding primacy to the welfare of rural populance. Agriculture is also believed to be a potential source to generate primary surplus to fuel the growth of other sectors of the economy (industry),

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[i] Ethiopia: Sustainable Development and Poverty Reduction Program. Federal Democratic Republic of Ethiopia. Ministry of Finance and Economic Development; July - 2002; Addis Ababa Ethiopia.

[ii] ibid. page i.

- strengthening private sector growth and development especially in industry as means of achieving off-farm employment and output growth (including investment in necessary infrastructure),
- rapid export growth through production of high value agricultural products and increased support to export oriented manufacturing sectors particularly intensified processing of high quality skins/leather and textile garment,
- undertake major investment in education and strengthen the ongoing effort on capacity building to overcome critical constraints to implementation of development programs,
- deepen and strengthen the decentralization process to shift decision-making closer to the grass-root population, to improve responsiveness and service delivery,
- improvements in governance to move forward in the transformation of society, improve empowerment of the poor and set framework/provide enabling environment for private sector growth and development,
- agricultural research, water harvesting and small scale irrigation and
- focus on increased water resource utilization to ensure food security.

The paper states further "… the strategy is built on four pillars (building blocks). These are: agricultural development led industrialization, justice system and civil service reform, decentralization and empowerment, and capacity building in public and private sectors."[iii]

The development program and all these "building blocks" may need an extended availability of distributed information base.

The agriculture accounts for 45% of the gross domestic product of the country for the year 2000/2001[iv]. By taking in to account the fact that only an estimated 3% of the countries food crop production is based on irrigation[v] and 85% of the population is a full time engaged private-subsistence farmer, it is not hard to see how heavily the countries rural economy is based on a seasonal timely rain. As it is observed in the recent past, the primary challenge to the subsistence farmers of the country, consequently the macro-economy, is the irregularity or total absence of the rain in the expected season – after each household have invested thousands of working hours on their farming fields, sawing their expensive seed and fertilizer - on which they can never have a direct influence. When the rain completely fails, the other wing of their economy - the cattle breeding – will soon come under a strong pressure due to the lack of grazing grass and water.

The working document shows further that, the government has planned to develop around 53 000 hectare of irrigation[vi]. Otherwise, the bulk of the strategy is inherently heavily based on the unknown and unforeseeable factor, namely a seasonal, timely and enough rain. Unless an economically feasible and sustainable introduction of water conservation/management mechanism for all climate regimes – and virtually for each groups of villages - is in place, it is hardly possible to attain the anticipated food security by the government.

[iii] ibid. page iii.

[iv] ibid. p. 33, figure 4.1.

[v] ibid. p. 87.

[vi] ibid. page 46.

In this regard it will be imperative to develop and implement a sort of nation wide drought-reversal and famine-preventive adaptive policy, which in its best scenario can be based on the introduction and routine implementation of "the state-of-the-art environment/water management technology coupled with a hydro/wind/solar electric generation" by using financial incentives and other business encouraging mechanisms for those highly specialized and well qualified private "will be" companies - by facilitating and allowing them to conclude agreements over a long period of time (possibly over several decades), making the work legally secured, profitable, attractive, and wholeheartedly implementing the fundamental property right - governed by the rule of law.

The implementation and realization of the well articulated three years framework plan of the government will certainly depend on how well and "reality based" the work on the ground will be done, the degree of transparency and accountability of the institutions involved in it, combined with the emplacement of a highly professional and efficient quality-control mechanism at the coupling interfaces or nodes.

Here, a reliable and robust information infrastructure may have the most crucial role. There have to be a fully functional backbone geographic/geometric and/or attribute database server system - as ray of discrete and disconnected "operational units" working autonomously (local intranet and/or local area network) - which are based on an "optimized" Total Cost of Ownership (TCO) at least at the woreda (district), regional, and federal government levels already in place. These have to be reliably standardized. The scalability, security, replication/(proper data synchronization), data consistency/integrity, data warehousing (which will support the decision process needs), and the high availability have to be guaranteed. The data entry points have to be clearly defined and maintained. Since the telecommunication infrastructure is not every where available and at some places not reliable, data transfer/actualization/replication among these servers and "operational units" may be securely done by implementing a policy of using such data carriers as CD-ROM from the clearly authorized source units "publishers" to the target units "subscribers" in a regular, timely, and routine manner.

The proper introduction of information technology, GIS included, may help in securing a reliable, optimal planning and transparent execution of the economical, social and environmental processes which may contribute decisively to the fulfillment of the above discussed government program. However, detailed policy actions with regard to information technology implementation measures needs to be clearly spelled out and the public at large have to be well informed, including an assessment of which applications and utilities have the greatest impact, in order to help prioritize them. Beyond that, the opening and operation of a dedicated computer/electronic technology college/institute would be the appropriate answer to the overall huge information infrastructure deficit of the country.

Recommendation

The GIS data base in this work showed a very high data integrity, scalability and information management facility, which can lead each task to a well coordinated target oriented process. Such an information infrastructure can help in clarifying the negative impact of cumulative social process on the environment and its possible mitigation. For any future negative cumulative impact mitigation and meaningful environment management, digital information infrastructure is indispensable. Towards this end, GIS technology may play a critical role. The build up of key digital environment infrastructure should be considered as a compulsory, which needs the proper attention from the local and federal government agencies.

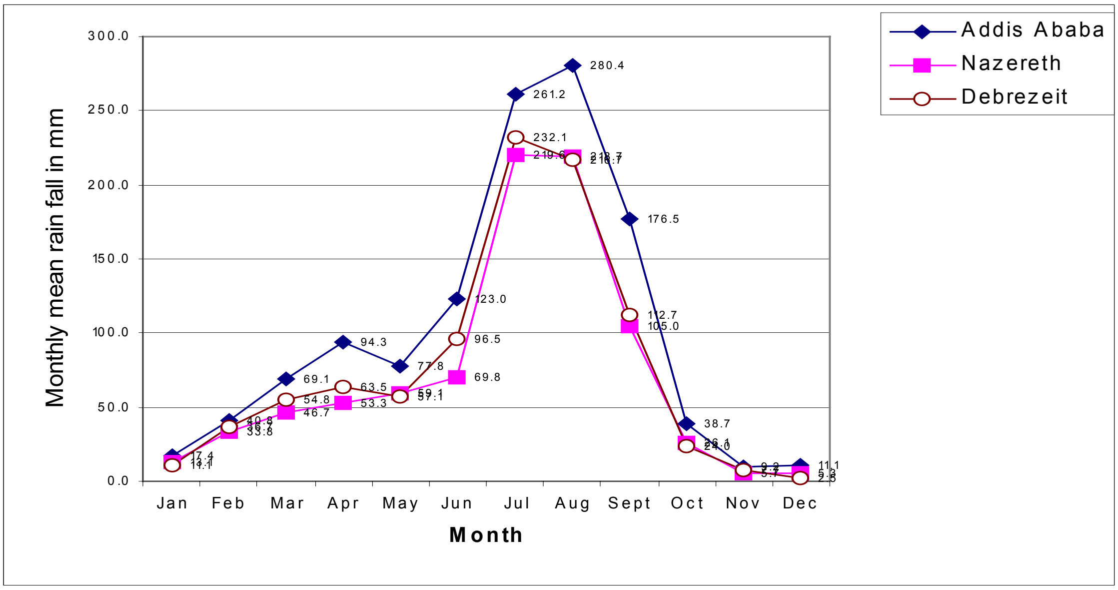
The recent short/medium term development program of the government shows an inherently heavy dependency on a seasonal, and timely rain. Unless an economically feasible and sustainable introduction of water/environment conservation/management and local hydro/wind/solar electric generation adaptive-policy for virtually each group of village is in place – based on the specific environment architecture (the geology/geo-morphology, native natural flora and fauna, climate regime and meteorology) of a given local area - the rural agriculture development would remain permanently dwarfed and the subsistence farmers may most likely be captured in a cyclic destitution.

Up to now, there is no detailed environment management policy in place, either from the local or from the central governmental institutions for the study area. Neither there is a policy for drinking water management, nor there is any protected water catchment area or surface water recharge location. In any new development planning, there have to be a regional agricultural utility and environmental preservation plan, which outlines and prohibits converting watershed as well as environmentally sensitive areas into farmland. A new culture of building water protection area, awareness of environmental balance and securing enough clean water in every rural community should be appreciated, for example by exempting from payment of tax and other attractive incentives.

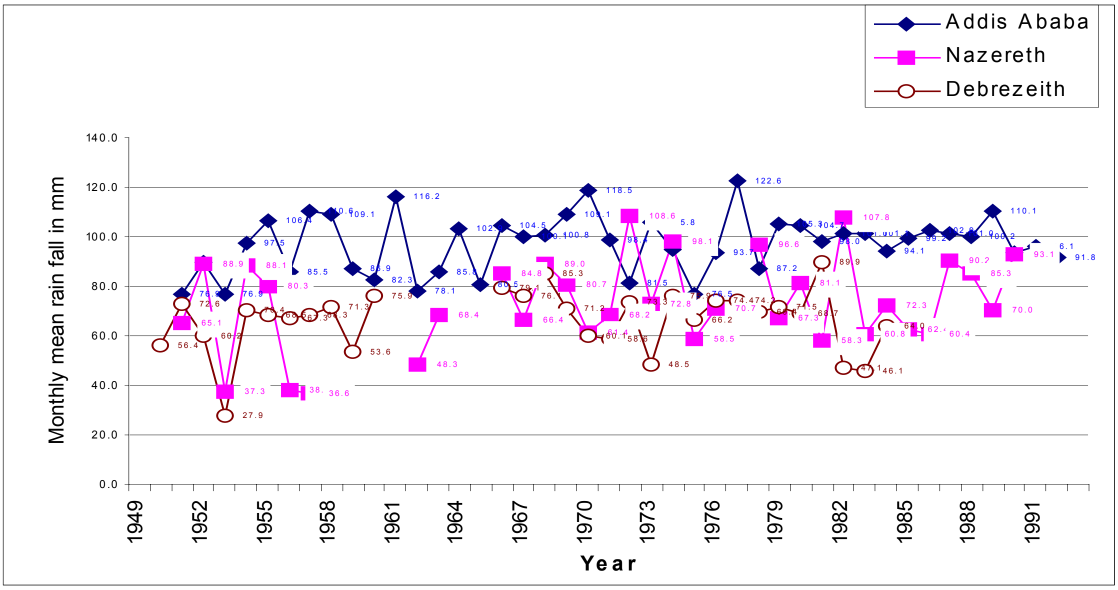
The financial/technical capacity of the villagers in the study area - for any meaningful water/environment conservation undertaking - is very weak, while they could make a huge labor power on a short notice available. The demand for water and energy by them is increasing steadily. There is a clear disparity between demand and supply in this regard.

Based on the results of this study, an integrated approach to the surface/groundwater as a single entity is recommended. The approach of building “many small” dams more frequently upstream at the valleys - along the escarpments and plateaus is more preferable. This causes the deceleration of the erosion, and less evaporation. Additionally, the availability of water for the villages around these high land localities will be secured, the villages in the lowland area and in the rift valley can get clean water in form of ground water in their vicinity. In such a method, the risk of mineralization on the rift floor could also be confined. Besides this, a wide possibility will be opened for the construction and operation of several “decentralized and small” hydroelectric power-stations for a local consumption.

Concerned institutions should develop and implement a long term adaptive-policy first to mitigate the scarcity of drinking water and local energy base. Parallel to the mitigation some locations - depending on the environment and social considerations - from the plateau, escarpment and lowland areas could be selected and pilot projects on environment regeneration, rain water harvesting, groundwater and spring reinforcement, small size water reservoir construction and energy generation should be done. Depending on the results and experiences, multiple of such adaptive-projects and economically meaningful operations could be conducted. Since the study area is highly populated, the owners of the locations - which may be selected for such conservation - should get a sustainable and economically meaningful compensation. In a most practical case, those people could be coupled to the respective specific projects by integrating them as the partial owner and supplier of the locally generated electric energy as well as water. This can be seen and further encouraged as a sort of specialization and labor division among the villagers.



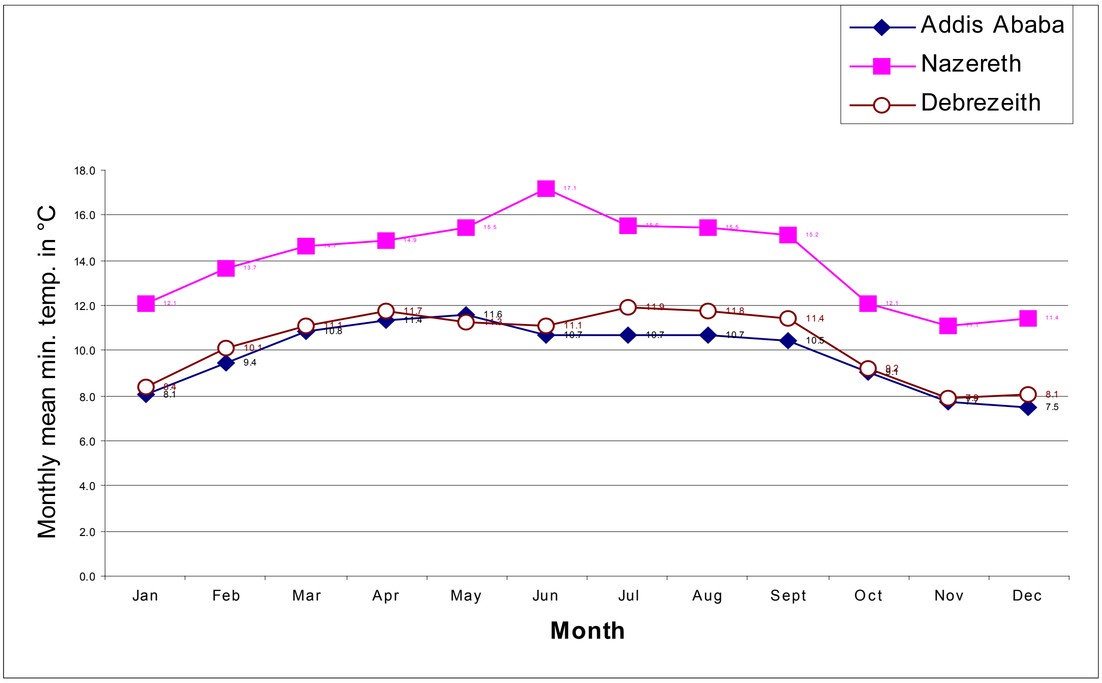
a)



b)

Figure 1. Monthly mean a) and monthly mean yearly average b) rainfall for Addis Ababa (1949-1993), Nazereth (1953-1993), and Debre Zeit (1958-1993).

a)



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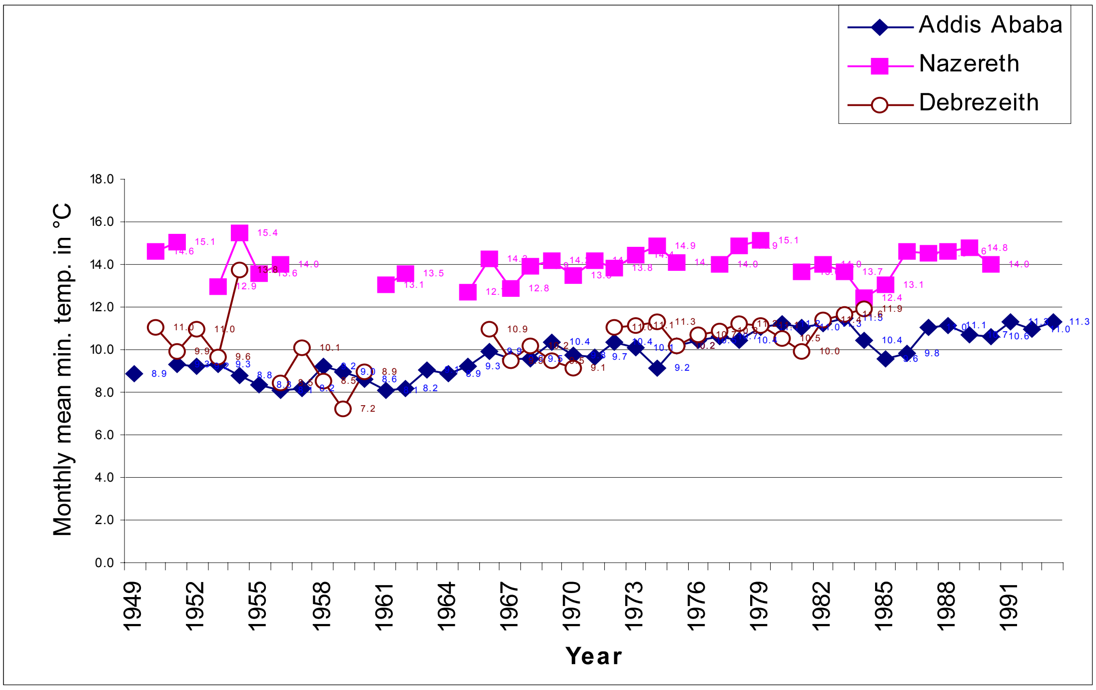
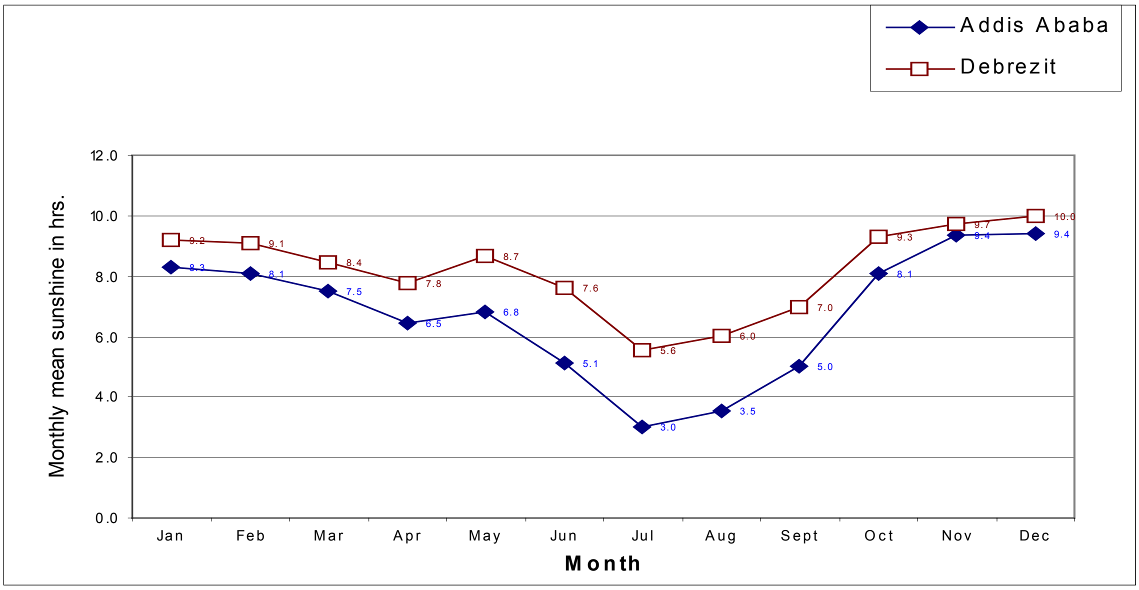


Figure 2. Monthly mean a) and monthly mean yearly average b) minimum temperature for Addis Ababa (1949-1993), Nazereth (1953-1993), and Debre Zeit (1958-1993).

a)



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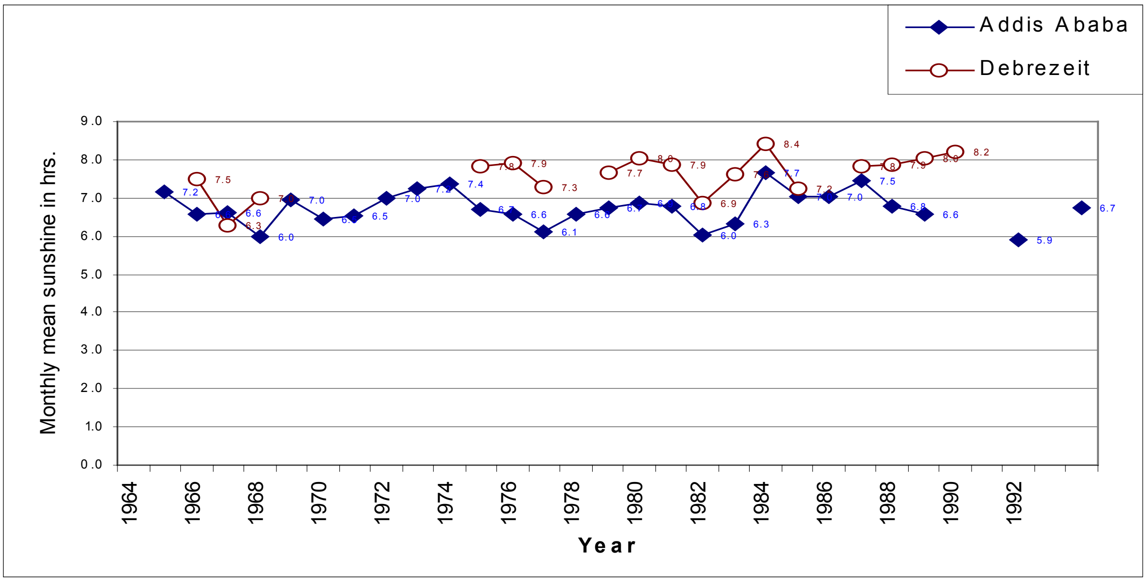
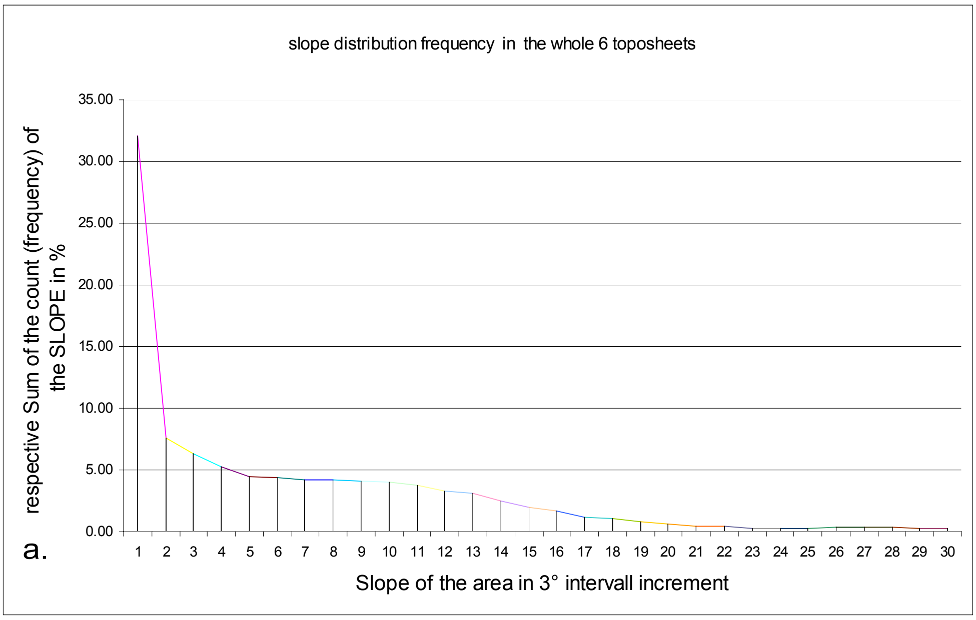


Figure 3. Monthly mean a) and monthly mean yearly average b) sunshine for Addis Ababa (1949-1993), and Debre Zeit (1958-1993).

a)


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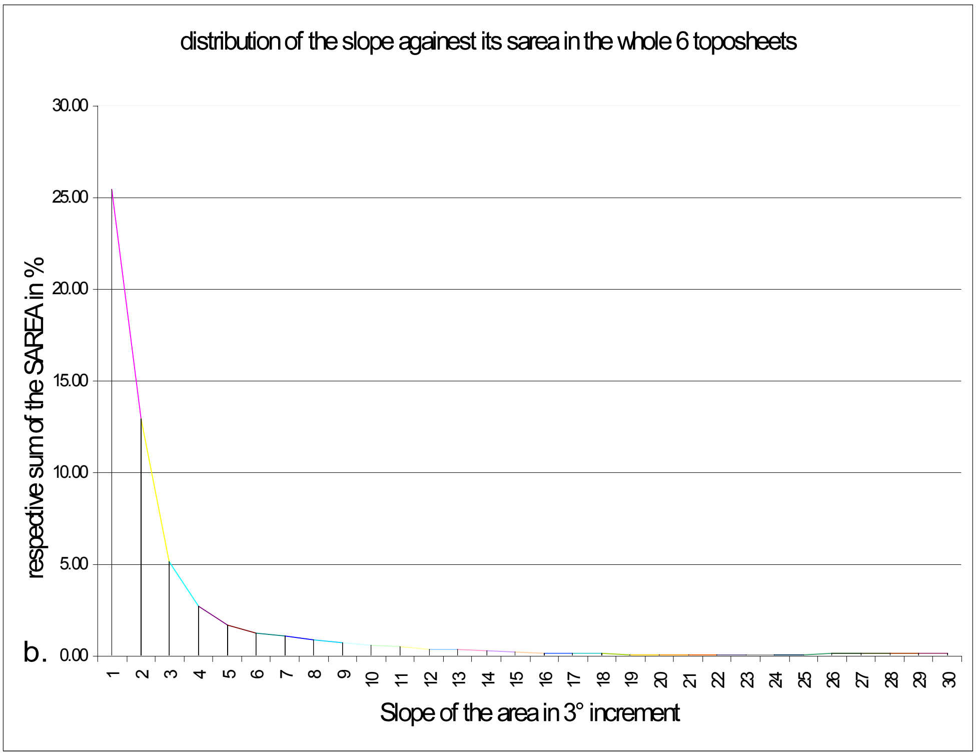
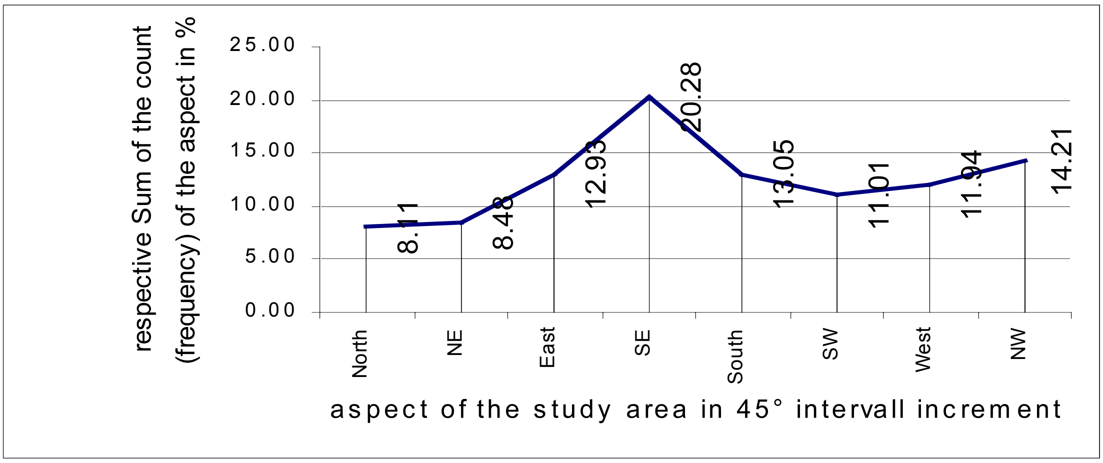


Figure 4. Slope of the study area with a slope increment of 3° a) with respect to the occurrence frequency and b) with respect to the respective covered total surface area, sarea.



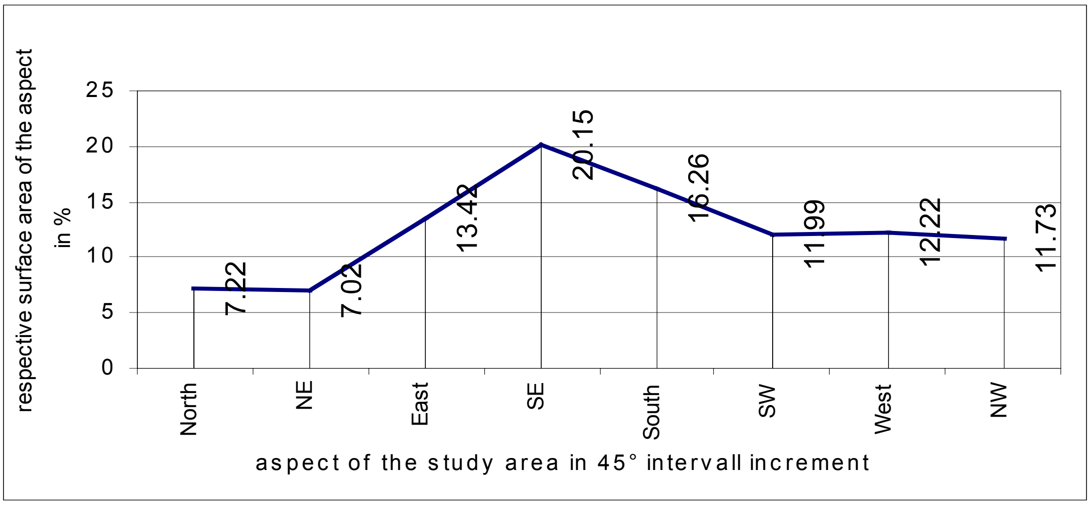
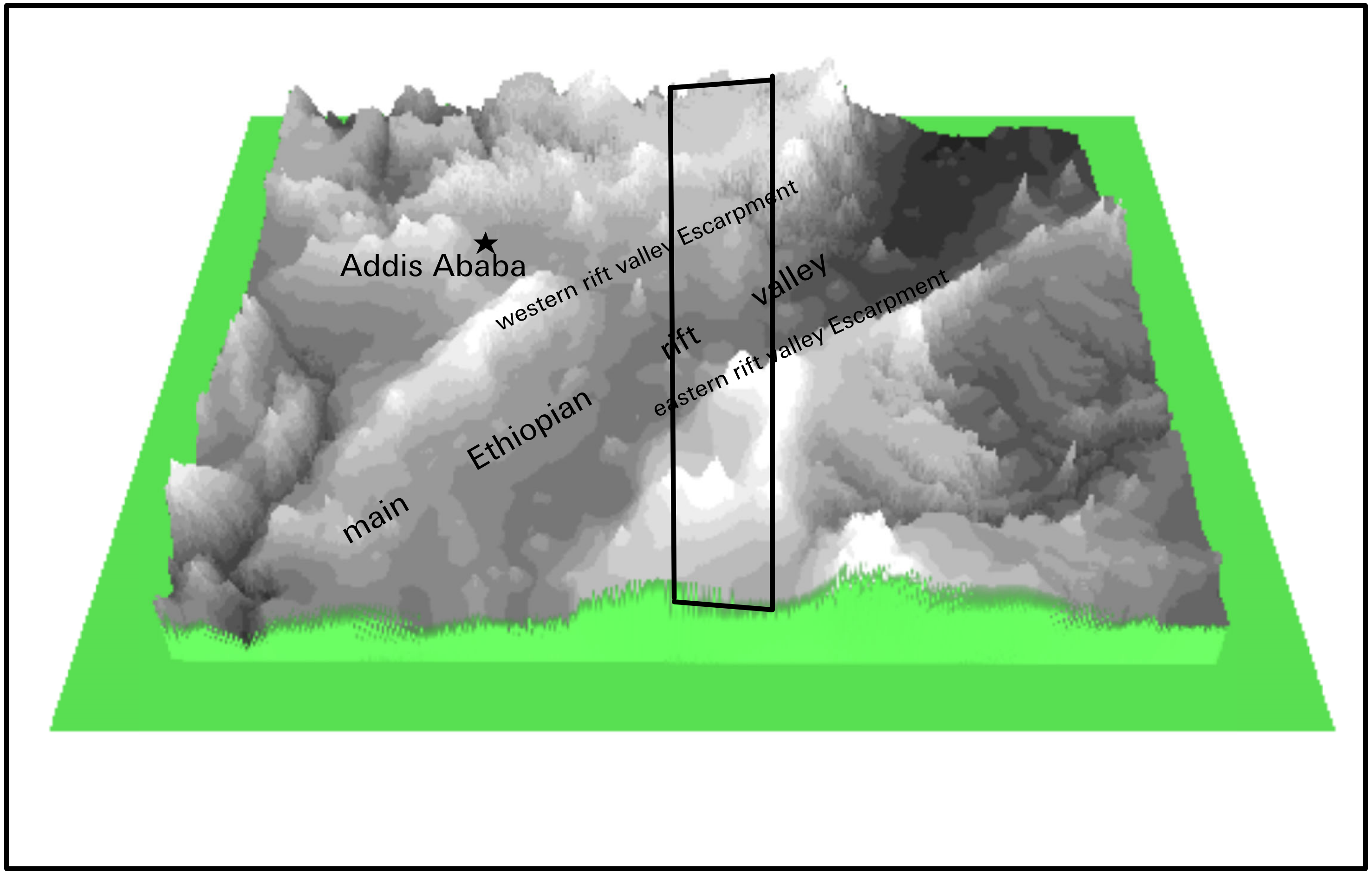


Figure 5. Distribution of a) the sum of the coount (frequency) of the aspect and b) the surface area covered by the aspect against the compass direction in 45° interval, after reducing the value 9999, which is 50.7% of the total surface area.



OBSERVATION POSITION:

...x= 509437 meters, y= 420090 meters

...AGL= 26293 meters, ASL = 26293 meters

..Direction:

...FOV: 50, Pitch = -45

...Azimuth: 0, Roll = 0.

SCENE PROPERTIES:

...DEM Exaggeration: 20

...Viewing Range: 1010400 meters

SUN POSITIONING:

... Azimuth: 64.8° (0-360°)

...Elevation: 90° (o-90°)

...Ambience: 0.7 (0-1)

Figure 3. Observation from the south on the TM full scene area, using the 1:250000 USGS DEM data.

It shows the physiography of the central part of Ethiopia.

by Mezemir Fikre-Mariam Wagaw, Feb. 2001

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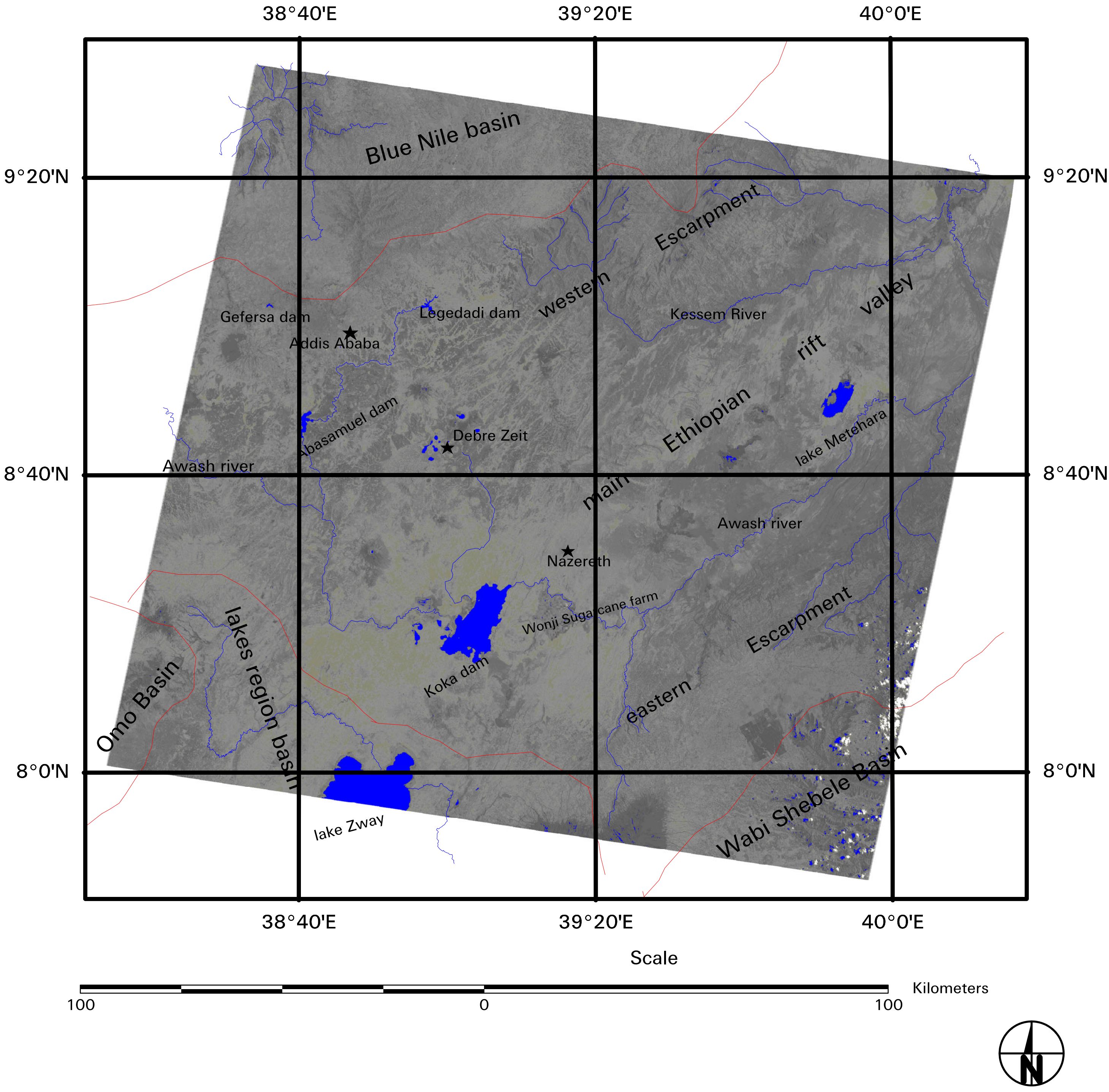

Map 2. Maximum likelihood classification applied on the PCI transformed Landsat MSS, overlaid with the main rivers and water shade coverage. The blue class represents the surface water body of the area. In this classification the cloud shade - mainly at the south east area - and the water body are resulted in to the same pixel class.

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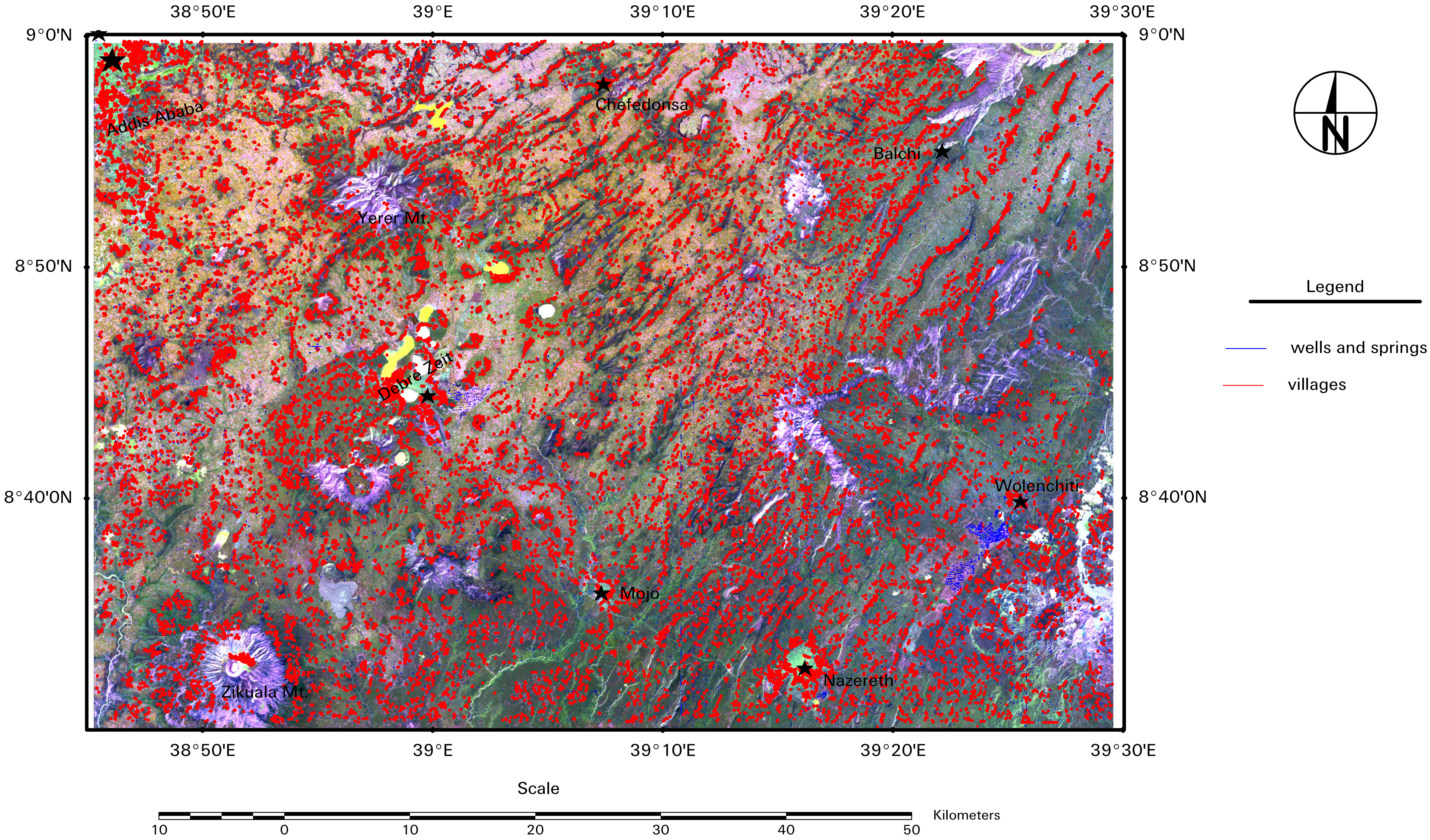

Map 16. Landsat TM ratio combination (x2/x5, x1/x2, x1/x7) in RGB respectively, overlaid with the village, well and spring coverages.

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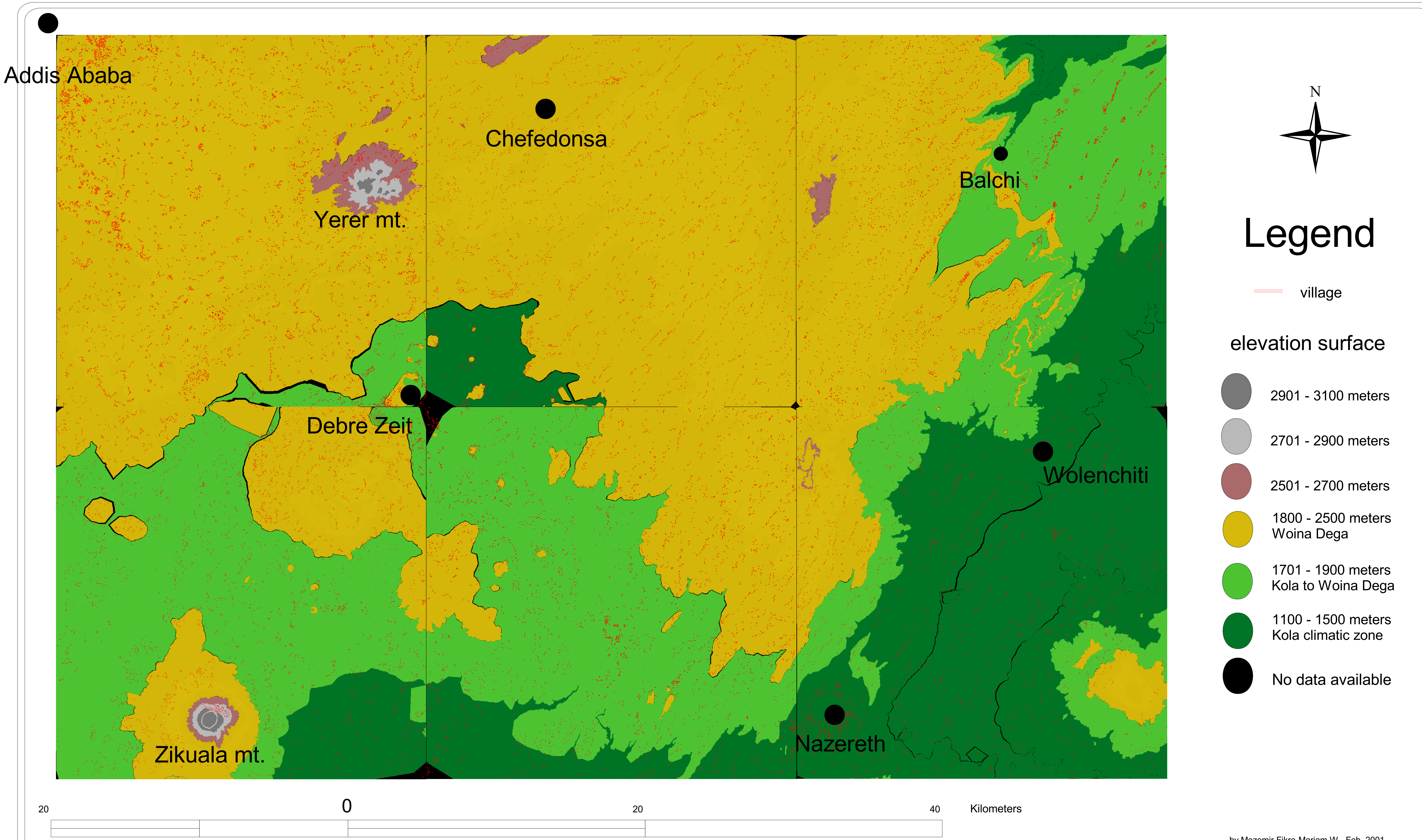

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Map 19. The climatic zones Dega, Woina Dega and Kola represented with their respective elevation surface overlaid with the village distribution vector.