

## **MONITORING AND EVALUATING LAND USE/ LAND COVER CHANGE USING PARTICIPATORY GEOGRAPHIC INFORMATION SYSTEM (PGIS) TOOLS: A CASE STUDY OF BEGASHEKA WATERSHED, TIGRAY, ETHIOPIA**

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### **ABSTRACT**

Agricultural land degradation in Ethiopia leads to an annual loss of roughly 2 million cubic meters of top soil. The relationship between this loss of soil quality and declining agricultural productivity is increasingly threatening rural livelihoods, putting pressure on urban centres as people migrate, as well as on very scarce forest resources on which the agricultural systems eventually depend. Attempts to address land degradation have required the government of Ethiopia to fully understand the underlying social and ecological drivers of land degradation. In order to fully develop the knowledge portfolio required to design and implement land rehabilitation measures in remote areas experiencing degradation, an adaptable, robust and credible system of ethno-ecological knowledge representation, analyses and communication is required. This is needed not only to bridge the technological gap between the rural and urban areas but to facilitate the representation and integration of both temporally and spatially explicit historical and 'real time' knowledge, held within rural environments. This paper describes the application of participatory geographic information systems (PGIS) tools and approaches in Tigray, Ethiopia. In this application to generate both current and retrospective information of land use processes, the use of PGIS focuses on methods of knowledge 'capture', representation and communication through the graphic representation of both past and present land uses using rudimentary tools. The information gathered in the process is then transferred into a Geographic Information System, for additional analyses, sharing with scientists and onwards transmission to decision makers and other users in a form which they respect, can understand and reproduce. The practice of PGIS in this setting in Ethiopia has encouraged broad-based participation at community levels, improved within-community communication and provided opportunities for greater social inclusion in development processes.

**Keywords:** PGIS, GIS, land cover, Tigray, Ethiopia

## INTRODUCTION

### **Land Degradation Problems in Ethiopia**

Land is a complex and dynamic combination of factors: geology, topography, hydrology, soils, microclimates, and communities of plants and animals that are continually interacting under the influence of climate and of people's activities (Hudson, 1995).

The variations in land must be identified, characterized and the information communicated via the most inclusive and cost-effective means if people are to understand the different forms of land use, the hazards of accelerated changes and degradations that could accompany those uses. In Ethiopia, farmers mainly use this basic resource in traditional ways without any logical organization of different types of land according to their agricultural potential or according to their physical configuration (Hudson, 1995). This leads to further degradation of the soil and disruption of agricultural production resulting in the poor performance of the agricultural sector in particular, and the whole economy in general. However, continued agricultural growth remains a necessity, not an option, for most developing countries like Ethiopia and this growth must be achieved on a sustainable basis not jeopardizing the underlying natural resource base or to impose costly externalities on others (Fitsum, 2003).

Land degradation is the most notable phenomenon in Ethiopia and particularly in the study area. At the turn of the century (1900), about 40% of the landmass of Ethiopia was under forest cover, but currently this figure is below 3% (EFAP, 1994). Out of the estimated 60 million ha of agriculturally productive land in Ethiopia, about 27 million ha is experiencing erosion, 14 million ha considered eroded and requiring rehabilitation and 2 million ha is considered lost; with an estimated total loss of 2 million m<sup>3</sup> of top soil per year with an average annual soil loss from cultivated lands of 100 tons/ha (FAO, 1986).

### ***The Potential of Local Knowledge in Land Management Programmes***

Centralized knowledge, urban influences and values have predominated in the natural resources management sector in Ethiopia over the years and often failed to recognize the knowledge that rural people possessed of natural resources (Chambers, 1991). The watersheds on which soil erosion and soil loss have occurred are for instance characterized by long-established sedentary and agrarian populations. It thus became prudent that, participatory approaches were needed to better understand the socio-cultural context of these erosion-prone sites. Participatory rural appraisal methods were thus seen as essential to both the understanding of the real situation occurring on the ground and for developing adequate policies, aimed at ensuring the sustainability of any plans and techniques to be instituted as part of watershed management programmes (Perez, 2003). To this end, it was considered that a hypothetical course of action involving an adaptable information system, robust, yet inclusive enough to represent local knowledge and suggestions was needed as part of a possible management process. Such a system it was decided would not only represent local knowledge of realities prevailing on the watershed but would also capture historical perspectives crucial in understanding present and past dynamics and potential mitigation actions. Participatory geographic information systems or PGIS was thus considered as a plausible candidate for addressing the land degradation problem.

### ***Communications Opportunities in Participatory Geographic Information Systems***

A geographic information system (GIS) is a relational database whose main feature is the use of a common coordinate system for accessing both spatial data and descriptive or attribute information defining the objects under investigation (Mbile, et al., 2003). A GIS can be operated at different scales. However, the use of conventional GIS tools using conventional

data may not always produce promising results unless the communities in question participate fully in the process. If the data to be analyzed in a GIS is completely dependent on sources that exclude local knowledge, the information and the data created from its analysis may not represent the reality on the ground and policies produced from such analysis may be unattractive to local communities who may not then participate in all the steps required in the development process (Perez, 2003). Hence, by linking the information relevant to communities, with geographically explicit data conventionally found in a GIS, the hybrid methodology would strengthen the capacity of local knowledge within the multi-participant-planning processes (Mcconchie and McKinnon, 2002). The approach of using Participatory GIS (PGIS) is also aimed at avoiding the drawbacks of top-down impositions of opinions, in favour of technological approaches that attempt to understand the social and ecological foundations of traditional knowledge systems (Shah Parmesh, 1992).

An added advantage of PGIS is that it tends to involve more than one stakeholder in the planning process. Thereafter, the participatory use of mapping tools by all the different stakeholders for visualizing problems becomes instrumental in raising the level of multiple stakeholder participation and relationships in the eventual project implementation process (Hoare et al. 2002). Against the background of criticisms against conventional GIS, PGIS has evolved beyond the consideration of GIS as an “island of privilege” (Rambaldi and Tarr, 2001). Thus PGIS applications have evolved into an application of GIS that is more suitable in promoting stakeholder participation thus making the latter into a more benign tool for participatory development (Perez, 2003). PGIS is therefore an attempt to utilize GIS technology in the context of the needs and capabilities of communities who are involved with, and affected by; development projects and programmes (Abbot et al., 1998). The main use of PGIS is thus to enhance participation, empowerment, developing local skills in graphically representing ideas, problems (maps); to better analyze, communicate ideas of changes and to implement more sustainable projects. According to Zurayak (2004) PGIS in such contexts has been proven to be a useful, practical and cost effective tool that delivered the product it was initially meant to deliver: accurate geo-referenced information that is recognizable and readily adopted by the local communities and other higher-level stakeholders. PGIS was thus selected as a methodology for our work both on the merits of its conceptual basis and as a result of tested examples by practitioner around the developing world.

## **OBJECTIVES**

### **General Objective**

To facilitate the assessment of land use changes over the past 50 years in Tigray, Ethiopia, through the representation and evaluation of social and ecological drivers of that change as perceived by traditional knowledge systems.

### **Specific Objectives**

Specifically, this research sought to:

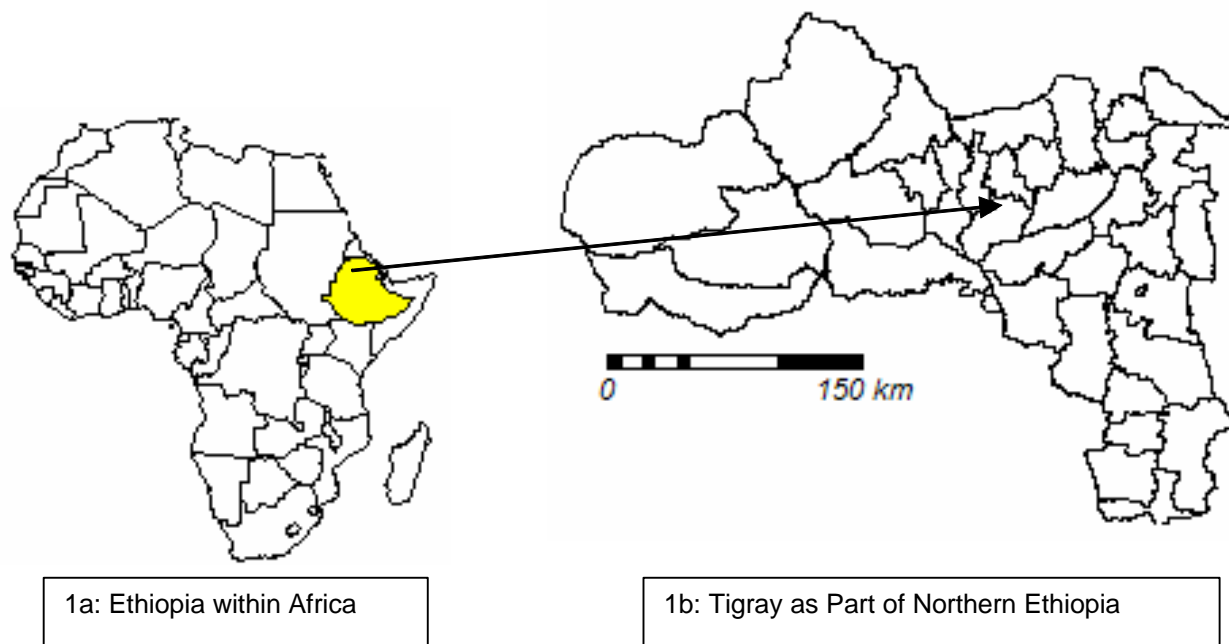
- Assess land use changes on the Tigray watershed using Participatory Geographic Information Systems (PGIS) learning and analyses tools
- Evaluate the extent to which local people, through mapping, can communicate information and thus knowledge about the changes
- Assess the feasibility of using PGIS in mapping resources at the grass roots level.

## METHODOLOGY

### Description of the Study Area

The study was conducted at *Begasheka* watershed located at  $13^{\circ}36' - 13^{\circ}39' \text{N}$   $38^{\circ}55' - 38^{\circ}57' \text{E}$  with an altitudinal range of 1739-1862m asl, in Tigray, Northern Ethiopia. The study area is characterized by semi-arid agro-climatic zone receiving an annual rainfall of 500-800mm and a temperature of 25-30<sup>0</sup>C. The two dominant types of soils are Cambisols and Arenosols (REST, 1994).

Heavy grazing, excessive deforestation and poor natural resource management observed in the area have contributed to the excessive degradation of the land. The dominant land use practice is arable land and the natural vegetation has been almost removed and relics of the remnant forest are found within church compounds, which are commonly called “church forests”. Since large parts of the land have lost their potential to grow annual crops or grass for livestock, the government and the local community have been implementing different soil and water conservation approaches. Among the conservation efforts enclosures appear more successful, wherein highly degraded areas are being protected from livestock and human interference, to enhance the land rehabilitation process.



**Figure 1. Study area**

It was observed that the forestlands which were once largely covered by climax vegetation (Figure 2a) were highly depleted and land degradation was the major problem (Figure 2b). With the land reclamation programs in the last 10 years, some places were enclosed from the encroachment of livestock and man and these showed some improvement (Figure 2c).

### DATA COLLECTION METHODS

The inhabited parts of the watershed from which data was collected included four villages. From each village elders who have lived in the area for more than 50 years, and who are well respected within the community were selected to participate in the process. After they were made to understand the objectives of the study, they were requested to represent by mapping; both the current and the past land use practices on the ground using stone, soil, leaves, etc.

The number of land use types were limited to three, Arable land, grazing land, and Forest land, because these covered more than 90% of the total land area. Land use practices considered by the local to be less significant were left out of the mapping process for purposes of simplifying the map.



*Olea europaea sub sp. africana* a dominant tree species once covered large parts of the study area, but now only relics are found in church compounds only



Over the past 50 years Severe land degradation has been a major phenomenon in the study area



In the last 10 years, there has been a strong effort to reclaim degraded lands through enclosures and vegetation cover has been thus improved. some places

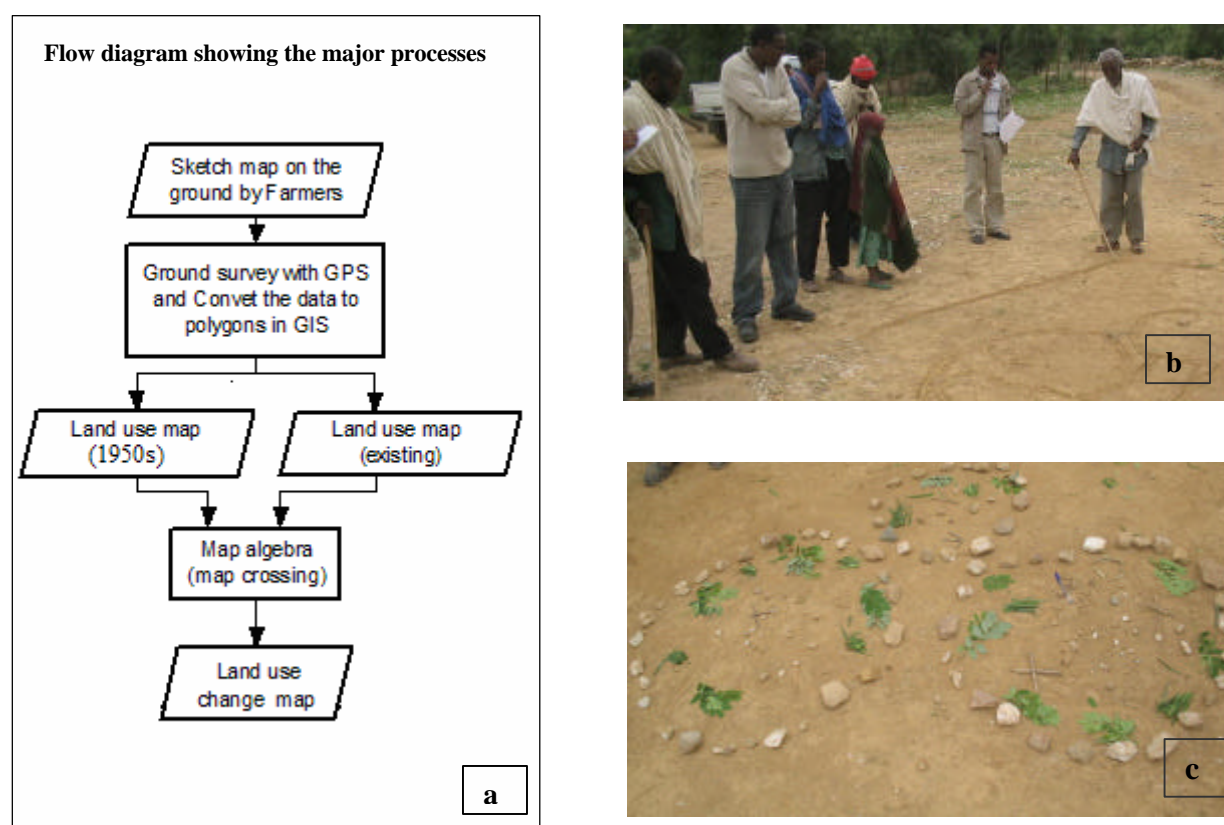
**Figure 2. Changes in land cover over time**

Once the two maps; one, retrospectively showing past land uses and the second, the current land use practices were produced, discussions focused on the accuracy of the two maps and some modifications were made by the villagers who finally accepted them. Both maps, drawn on the ground (Figure 3b, c), were then copied on to paper. After completion of paper sketching, an extended field survey, including the representatives of the group, was made to locate the boundaries of the different land use types with Global Positioning Systems

(GPS). The GPS data was introduced into a Geographic Information System (ILWIS 3.2) within which objects with area were converted to *vector* objects or *shapefiles*.

The vector based maps were then converted to digital images, and both the retrospective and current maps were then geo-referenced to 'real world' co-ordinates and superimposed (crossing), one on top of the other, to produce a visualization of land use change over time. (Figure 3a).

With the visualization complete, the major causes of land use changes in the study area were then assessed using a semi-structured questionnaire and focused group discussions with the village mappers.



**Figure 3. Method (a); one of the elder persons sketching the land use of 50 years ago (b); Existing land use map drawn using local materials (c)**

## 4. RESULTS

### Change in Land Use

In this PGIS assisted analyses the greatest land use change was observed in the conversion of forest to arable land (75%) followed by grazing to arable land (11%) (Table 3). The maps and tables showing the land use and land use changes are summarized below

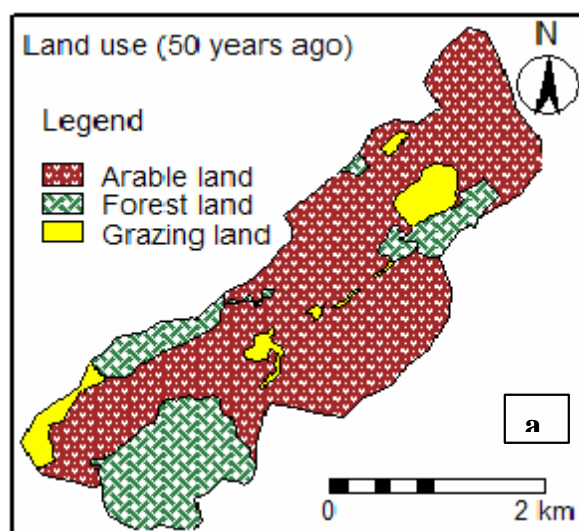


Table 1: Land use (50 year ago)

Land use	Area	
	Ha	%
Arable land	592	70
Forest land	195	23
Grazing land	56	7
Total	843	100

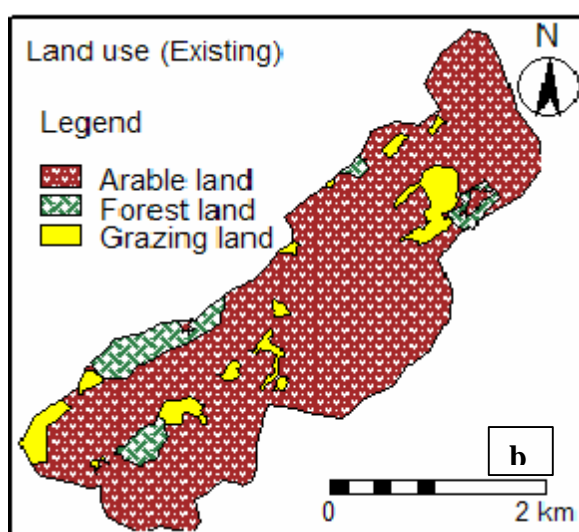


Table 2. Land use (Existing)

Land use	Area	
	Ha	%
Arable land	726	86
Forest land	56	7
Grazing land	61	7
Total	843	100

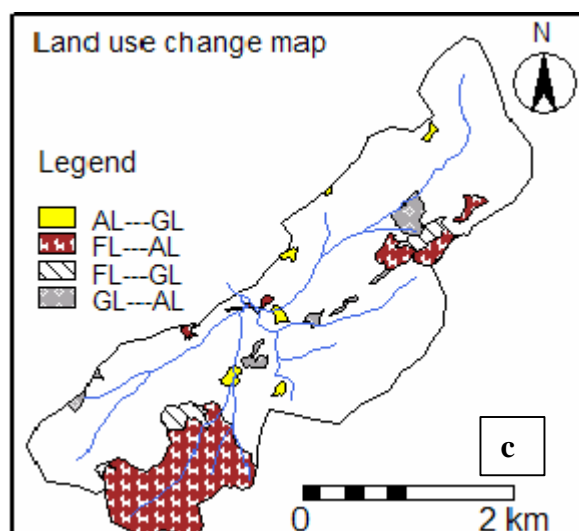


Table 3. Land use change

Land use change	Area	
	Ha	%
Arable land to Grazing land (AL---GL)	8	5
Forest land to Grazing land (FL---GL)	15	9
Forest land to Arable land (FL---AL)	124	75
Grazing land to Arable land (GL---AL)	18	11
Total	165	100

**Figure 4. Land use 50 years ago (a), existing (b) and the change map (c)**

Currently, arable lands are being changed to grazing lands when they lose their production potential for arable crop. According to results from group discussions, the major

causes of change in land use are increments in human and livestock population. The total population of the area has increased almost 10 fold which has forced the community to convert forest to arable lands in order to produce enough food. Moreover the level of technology to intensify farming systems remains low. Thus, the overall production per unit area remains very low. This then forces people to extend their farm size, encroaching into forest lands in the vain hope to feed the extra mouths.

### **Farmer Attitude Towards Participatory Geographic Information System Practice**

When the farmers were asked about the representation of historical information using sketch maps, they gave the answer with a local proverb: “*yekal yeresal yetsehuf yeweresal*” meaning, what is expressed in words can be forgotten but something represented in graphics such as on paper or in a GIS will be remembered. They did also emphasize the opinion that the mapping process was an effective method of indicating changes over time as well as facilitate representation of information of different geographic locations that they have had the opportunity to visit over time. In the process of mapping, farmers associated the temporal aspects with special occasions like drought years, marriage, death of known people, change of government, land reallocation, etc. and for spatial dimensions, they used existing infrastructures like churches, school, clinic drainage patterns, etc.

The Farmers also believed that the maps are a good way of representing their knowledge and contribution towards any land rehabilitation process. One of the farmers explained this idea that: “the leaders in the capital (far away) might know our place by name, but they might not know the actual resources and the problems that exist in the area. Thus, mapping could give them a good picture about the real situation and help them make better decisions develop appropriate development programs at a reasonable cost.

Farmers who were involved in the mapping process admitted that, they could not have expected such an easy mapping exercise to be something so potentially important serving as a medium of information generation, capture in a GIS and its communication to decision-makers many kilometers away. But when they came to learn that it is important and scientific they felt so proud of what they know and did.

### **CONCLUSIONS**

PGIS practice as used in this work provided a good opportunity for participatory problems analyses and in land resource management. It thus facilitated the bottom up transmission of information, thus re-enforcing the potential for influencing decision-making in a ‘bottom-up’ direction.

PGIS practice as a was found to be a useful, practicable, cost effective and non-conventional medium of communication using a language with which farmers could easily communicate with land management experts. With both its analog properties of information representation, moving on to digital ones (amenable) to new information and communications technologies, PGIS proved itself capable of transcending low-tech and hi-tech milieus in the land rehabilitation process in Ethiopia. This way information collected from Tigray will be integrated with that from other regions to help build an national land rehabilitation programme.

Through the participation of both men and women at equal levels, PGIS helped in providing a balanced representing of information from all social groups within the rural community. This facilitated intra-community communication and helped convinced the land management board official that, the knowledge was truly representative of experiences in the locality.



Compared to similar exercises carried-out elsewhere in Ethiopia, the practice of PGIS in understanding land degradation and to propose solutions proved to be simpler and more cost effective. There is thus the possibility of extending the activity to other communities with the results being left in the villages, such that similar activities are not repeated at high cost to the villagers.

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