Application of AHP for Environmental Suitability Analysis of Resettlement Site Selection: Chawaka District, Western Ethiopia

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Abstract
The most essential issue in a resettlement process is the selection of a most appropriate site that offers best of the features required for people to lead a reasonably satisfactory life. A relocation site, therefore, must be very carefully selected considering a plethora of environmental parameters, both of bio-physical and socio-economic nature as a good combination of these attributes ultimately govern the quality of life of the people going to be resettled. In order to evaluate this suitability, state-of-the-art RS and GIS techniques in combination with MCA tool were made use of in the present study in Chawaka of Western Oromia in Ethiopia. The ultimate outcome indicated that weather, soil, land-use/ land-cover and topography attributes of the site occupied the first four ranks in that order followed by infrastructure, proximity to towns, population density and health aspects from fifth to eighth ranks in that order. Suitability analysis based on these rankings revealed that 2.02% (12.68 km^2) of the Chawaka region as such is highly suitable for resettlement purpose, followed by 65.66% (412.20 km^2) area as moderately suitable and 32.3% (202.12 km^2) area as marginally suitable. Since moderately suitable area is sufficiently vast, the same can be chosen for promoting resettlement provided the drawbacks of health and proximity to towns are overcome by improving infrastructural facilities and road network to ensure a comfortable living to the resettlers.

1. Introduction

Resettlement or relocation is a social process in which people leave their original area of residence and settle afresh in a new area (Woube, 2005). Resettlements are foci of many economic, social and public programmes in Ethiopia. Governments have taken up this activity as one of the best strategies to address multi-faceted problems of social amenities, economic avenues and food security afflicting areas of high population density and severe ecological degradation. Further, resettlement programmes are sought after as a means of utilizing unused land for the development of settling landless peasants, unemployed persons and farmers from drought prone and over-populated highland areas (Kloos et al., 1990). These programmes also serve as basic tools to see to the settlement of pastoral nomads and ensure continuation of farming in private as well as state owned lands. Resettlement processes include several options right from finding places for temporary shelter to locations for construction of permanent houses in original or new places (Deruyttere et al., 1998). However, the major constraints faced by people affected by resettlement processes are loss of livelihood and income from arable land. Lack of proper social amenities such as hospitals and schools adds up to the miseries of people in resettlement sites (Dubie, 2005). Thus, people in vulnerable and hazardous areas have confronted with many a conundrum due to resettlement activities and are afflicted with a number of hydrological and meteorological issues (LSDR, 2006). Many relocation areas around the world stand now as testaments to the failure of the said programmes (Dubie, 2005, Karimi et al., 2005 and UN-HABITAT, 2006 and 2008). As a result, a phenomenal population moved back to their original lands though the rest are bound to stick to resettlement areas due to lack of other alternatives. Despite advocating and implementing different mitigation measures, the proportion of affected people have been on a rise over the years, evidently because of improper site selection. Therefore, the most fundamental issue of site selection is addressed in this paper through a case study in Chawaka of Western Oromia in Ethiopia. In a country like Ethiopia, where majority of the people are agrarian or directly dependent on nature for their livelihood, environmental suitability is one of the preeminent

features that determines a befitting relocation site. Environmental suitability is chiefly governed by spatial (bio-physical) parameters such as land-use/land-cover that reflect weather conditions, fertility of the soil, variability of the slope and non-spatial (socio-economic) parameters such as transportation, infrastructure and population density that reflect community intervention. During the present study, these parameters were initially identified through a preliminary survey in Chawaka, followed by their substantiation from literature (ADPC, 2006, Ozden, 2006, Teerarungsigul, 2006, Yumuang, 2006, Takesada et al., 2008 and Zahran et al., 2008). Literature further reveled that generation of accurate spatial information and non-spatial facts are crucial for planning future developments as well as sustainable management of natural resources gifted to man by the mother earth (Scudder, 1991). Chawaka is one of the districts resettled by people of Eastern and Western Harerge and is inhabited by 56,106 residents (CSA, 2007). The sole criterion considered while identifying this site for resettlement was availability of vast virgin agricultural land. However, none of the bio-physical and socio-economic factors were looked into in selecting the area for resettlement. Hence, the present study deals with the major environmental parameters that exercise a great bearing on human resettlement, and evaluate them in an integrated manner based on the state-of-the-art that incorporates remote sensing (RS), geographical information system (GIS) and multi criteria analysis (MCA) to arrive at a most suitable resettlement site for a successful resettlement programme (Jenson, 2000).

1.1 Study Area

The study area, Chawaka extending to 627 km^2 is located 556 km to the west of Addis Ababa between latitudes 8°44′48″ - 9°15′05″ N and longitudes 33°57′ 20″ - 36°16′17″ E (Figure 1). The area is highly undulating with elevations ranging from 1105 m to 2004 m asl. The area falls within *Dhidhessa* zone of Abay water shade system.

2. Material and Methods

Satellite imageries, Ethiopian Mapping Agency (EMA) maps and collateral data from various government organizations together with ground truth survey results were used in the present study. The data were analyzed and resettlement suitability sites were mapped using RS and GIS technologies. Ethiopian Mapping Agency toposheet (No.55) of 1: 50,000 scale was used for geo-referencing satellite images, creating resettlement areas and acquiring ground truth. Resettlement area boundaries (division, range, roads and network) extracted from the Working Plan and Oromia Water Works Design Supervision Enterprise (OWWDSE) were transferred on to maps. Landsat data of the entire resettlement area of late summer season for the years 2003-2005 were obtained from Global Land Cover Facility to ensure coverage. The geo-coded sub-scene of the study area (Path 170 and row 054) for the (2003-2005) was also acquired.

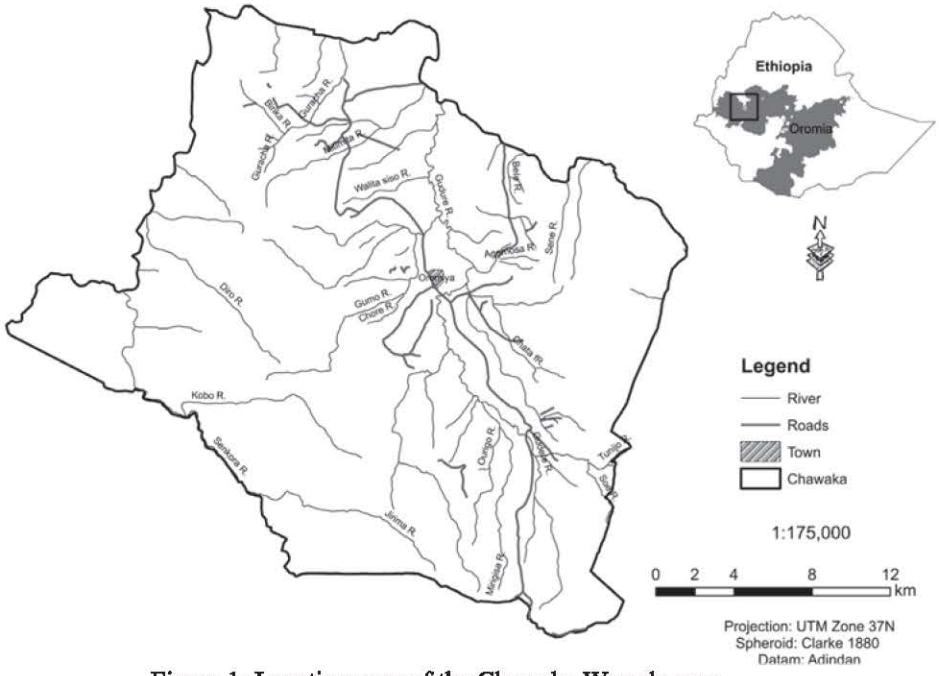

Figure 1: Location map of the Chawaka Woreda area

The satellite data so obtained were digitally rectified and processed using ERDAS Imagine 9.2 and ArcGIS 10.1 and used for the preparation of different thematic maps (land-use/land-cover, weather, soil features, topography and infrastructure). All top sheets pertaining to the study were mosaiced to aid in further analysis. All input data sets were geo-referenced in Adindin_UTM_Zone 37N coordinate system. Digital Elevation Model (DEM) of the area was obtained from 30 m resolution Shuttle Radar Topographic Map (SRTM) data to derive slope factor that facilitated topographic analysis (Peckham and Jordan, 2007). During the field data collection, Ground Control Points (GCPs) 32 points were selected for verifying the accuracy of land-use/land-cover classification. These GCPs and other location sensitive data was collected using Garmin 72 GPS satellite receiver. Each land-use/land-cover class was selected based on priority knowledge and ancillary field data. Accordingly, the overall accuracy of image classification in this study is 86.0% and its Kappa index agreement is 0.82. This implies that the classification process is avoiding 82% of the errors that a completely random classification generates. On the other hand, the accuracy of individual class varies from 64.71% to 91.67% for producer's accuracy and from 74.29% to 95.65% for user's accuracy. However, user's accuracy for bush and shrub land showed a value slightly less than 75%. With regard to producer's accuracy, all classes are accurate by more than 75% except for dense forest. Socio-economic data on health centers, schools, water source, road network and their distribution were obtained from Zonal Health Bureau of Ilu Aba Bora, Educational Bureau, Water Bureau and Trade, Transport and Communication Office of Chawaka, respectively. Details of the methodology were presented in (Figure 2).

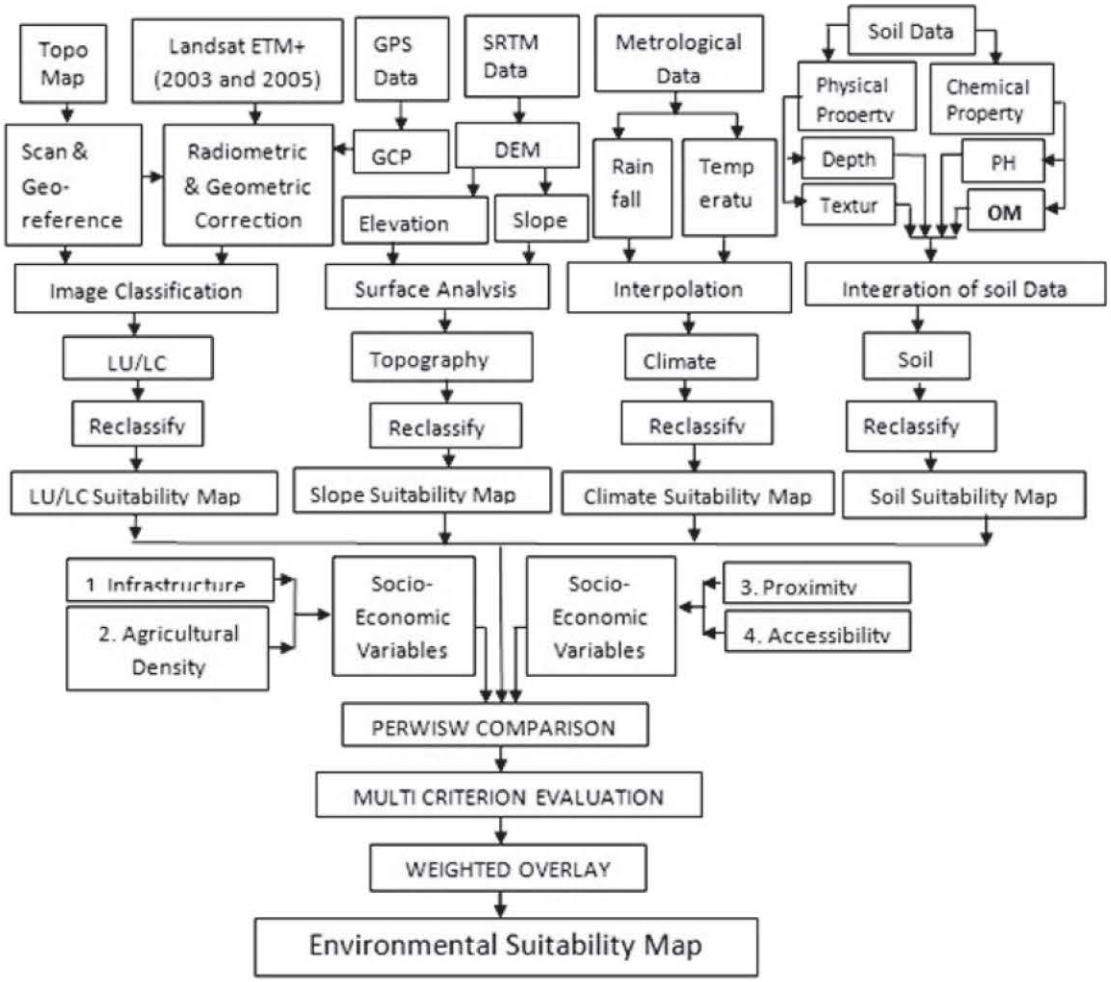

Figure 2: Methodology steps

2.1 Attributes, Criteria and Determining Factors

Bio-physical and socio-economic parameters that govern the suitability of a site for resettlement were used as attributes in preparing the suitability maps (Table 1). Based on their importance, critical value, practical relevance and availability of evaluation tools; each of the eight attributes was again distinguished into 1 to 5 criteria depending upon their relevance. In the case of population, density attribute calculated on the basis of ratio between farming Households and area of total arable land adopted by the "Ad-hoc Committee for Implementing Resettlement Program" (Mengistu, 1992 and Pereira and Duckstein, 1993) was considered so as to avoid crude density error.

2.2 Criteria Ratings

In order to establish criteria ratings, standards set by national and international institutions such as OWWDSE and FAO, previous scientific findings (Malczewski, 2006) and opinion of experts and researchers were considered. Sets of values that indicate the robustness of each criterion in satisfying bio-physical as well as socio-economic qualities were recognized into five classes, *viz*., highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable and assigned descending suitability factor ratings from 5 to 1 in that order (FAO, 1985, 1993).

2.3 Criteria Standardization

Reclassification method of spatial analysis tool within ArcGIS environment was used to compare and standardize spatial attributes data measured in different units and mapped in different scales (nominal, ordinal, interval and ratio) to obtain equivalent values and positive correlation among various parameters (Pereira and Duckstein, 1993).

Table 1: Attributes, criteria and ratings adopted in resettlement site suitability analysis

Attributes	Criterion	Suitability factors in decreasing order of importance (5 to1)				
		Highly suitable (5)	Moderately suitable (4)	Marginally suitable (3)	Currently not suitable (2)	Permanently not suitable (1)
A) Biophysical						
I. Land use/ land cover	1. Built-up area	√				
	2. Bush and shrub area				√	
	3. Cultivated area		√			
	4. Forest area				√	
	5. Grassland area			√		
II. Weather	6. Temperature (°C)	15-25	10-15	25-35	< 10	> 35
	7. Rainfall (mm)	1500-1800	1000-1500 and 1800-2000	500-1000 and > 2000	100-500	< 100
III. Soil	8. Depth (cm)	> 150	100-150	50-100	25-50	< 25
	9. Texture	Si, SiC, C	SiCL	SiL, CL, SC	L, SCL	S, LS, SL
	10. pH	5.9-7.7	5.5-5.9 and 7.7-8.0	5.2-5.5 and 8.0-8.2	4.9-5.2 and 8.2-8.5	< 4.9 and > 8.5
	11. Organic matter (%)	> 3.00	2.50-3.00	1.75-2.50	1.00-1.75	< 1.00
IV. Topography	12. Slope (%)	2-8	<2	8-16	16-30	>30
	13. Elevation +MSL (m)	2300-3200	1500-2300	1000-1500	< 1000	> 3200
V. Health aspects	14. Malaria risk (Individuals/km^2)	>2000	1800-2000	1600-1800	<1600	---
B) Socio-economic						
VI. Proximity to towns	15. Proximity to towns*(km)	< 25	25-50	50-75	75-100	> 100
VII. Infrastructure	16. Proximity to roads network (km)	< 2	2-3	3-5	5-7	> 7
	17. Proximity to schools (km)	< 1	1-3	3-5	5-7	> 7
	18. Proximity to health centers (km)	< 3	3-5	5-7	7-10	> 10
	19. Proximity to water supply (km)	< 0.5	0.5-1.0	1.0-2.5	2.5-4.5	> 4.5
VIII. Population density	20. Population density (ha/hh)	> 2.0	1.5-2.0	1.0-1.5	0.5-1.0	<0.5

Si - Silty; SiC - Silty Clay; C - Clay; SiCL - Silty clay loamy; SiL - Silty loamy; CL - Clay loamy; SC - Sandy clay; L - Loamy; SCL - Sandy clay loamy; S - Sand; LS - Loamy sand; SL - Sandy loamy; * - Striate line (radial) distance from Ilu Harer town; ha/hh - Hectares per household

Table 2: Land area covered by each attribute under various suitability classes

Sl. No.	Attribute	Land area									
		Highly suitable (5)		Moderately suitable (4)		Marginally suitable (3)		Currently not suitable (2)		Permanently not suitable (1)	
		km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
1	Land-use/ land-cover	0.56	0.09	140.45	22.40	92.23	14.71	393.76	62.80	----	----
2	Weather	211.24	33.69	415.76	66.31	----	----	----	----	----	----
3	Soil	----	----	504.36	80.44	122.64	19.56	----	----	----	----
4	Topography	----	----	374.76	59.77	252.24	40.23	----	----	----	----
5	Health aspects	----	----	12.54	2.00	112.86	18.00	250.80	40.00	250.80	40.00
6	Proximity to towns	----	----	----	----	627.00	100.00	----	----	----	----
7	Infrastructure	29.34	4.68	173.62	27.69	191.86	30.60	132.11	21.07	100.07	15.96
8	Population density	28.03	4.47	425.61	67.88	172.80	27.56	0.56	0.09	----	----

2.4 Assigning Criteria Weights

All bio-physical and socio-economic suitability parameters were exported to IDRISI Andes GIS software environment for purposes of pair-wise comparison based on their relative importance with reference to the objects (Eastman et al., 2005). Thus, relative criterion weights in the form of eigine vectors that sum up to 1 in each instance were arrived at (Table 2). This process took care of generating pair-wise comparison matrix (ratio matrix) while producing a consistency ratio to indicate the degree of any error allowed in computations.

2.5 Aggregating Criterion Weights and Producing Criteria Maps

Criteria maps, i.e., suitability maps for each attribute as well as suitability map for all the parameters together were developed based on the capability of GIS to generate maps and aggregate the criteria on the basis of weighted and vector overlay analysis technique (Jiang and Eastman, 2000 and Malczewski, 1996, 1999 and 2006).

3. Results

The overall suitability levels of the entire gambit of bio-physical and socio-economic attributes employed in the study are summarized in terms of their areal coverage and per cent share (Table 3).

3.1. Suitability of Bio-Physical Attributes

3.1.1. Land-use/ Land-cover

Based on remote sensing images, land-use/ land-cover of the study area was classified into five categories, *viz*., built-up area, bush and shrub area, cultivated area, forest area and grassland area. Built-up area comprised of small pockets of land used by resettlers for the construction of houses, schools, clinics and administrative buildings representing a diminutive proportion of 0.09% (0.56 km^2) of the total Chawaka region. Bush and shrub area composed of diverse plant species raising upto 2 m height covered as large as 45.73% (286.73 km^2) of the total region. Agriculture is the dominant economic activity of the people in Chawaka. Sorghum, maize, rice, soya bean, sesame, ground nut, haricot bean, accounted for 22.40% (140.45 km^2) of farming in the region. In addition, cash crops including '*chat*', different kinds of spices and other tree crops are grown. Animal fattening for commerce too Livestock rearing for meat is becoming a common practice. Retail trading of commodities, minor industrial products and consumer goods are also produced while other commercial products are largely obtained from nearby big towns like Bedele and Nakamte.

Forest area occupied 17.07% (107.03 km^2) of the region and is dominated by diverse species of high growing tress usually found around rivers and streams abundant in water. This land cover has been providing fire wood for household consumption thus serving as a major energy source to the locals. Land-cover of grassland area spreading over 92.23 km^2, (14.71%) of grasses of different species sparsely interspersed with trees, bushes and shrubs. This geographical area is potentially suitable for expansion of crop cultivation. An analysis of land-use/ land-cover attribute in the study area showed that only a meager portion (0.09% - 0.56 km^2) is presently under built-up area, which in highly suitable for resettlement purpose. On the other hand, 22.40% (140.45 km^2) is currently under cultivated area which is moderately suitable while 14.71% (92.23 km^2) is presently under grassland area which is only marginally suitable for resettlement. The remaining major portion (62.80% - 393.76 km^2) is occupied by bush-shrub and forest areas which are not suitable for resettlement (Figure 3).

3.1.2 Weather

Weather suitability was scaled based on temperature and rain fall requirements of dominantly cultivated major crops in the region. The district experiences a regular pattern of temperature variation right from 13° to 26°C with the mean temperature of 20°C. Precipitation in the area, almost distributed throughout the year, ranges from 1396 mm to 2014 mm with an average of 1816 mm. Spatially, the south eastern and western parts of the district receive highest rainfall, northern part receives the lowest. Temporally, the rainfall manifests as a mono-nodal phenomenon with 54% annual share contributed by the rainy season spreading from June to August followed by autumn (September - November), winter (December - February) and spring (March - May) with 24%, 2% and 19%, respectively. Combined consideration of these two components indicated that 33.69% (211.24 km^2) of the total Chawaka district having 15-25°C temperature and 1500−1800 mm rainfall is highly suitable whereas the rest of 66.31% (415.76 km^2) area having <15°C and >25°C and <1500 mm and >1800 mm rainfall is moderately suitable (Figure 4a).

3.1.3 Topography

As much as 476.52 km^2 (76%) of the total study area lies between 1500 m−2300 m asl within "*Midland*" agro-climatic zone moderately suitable for human settlement.

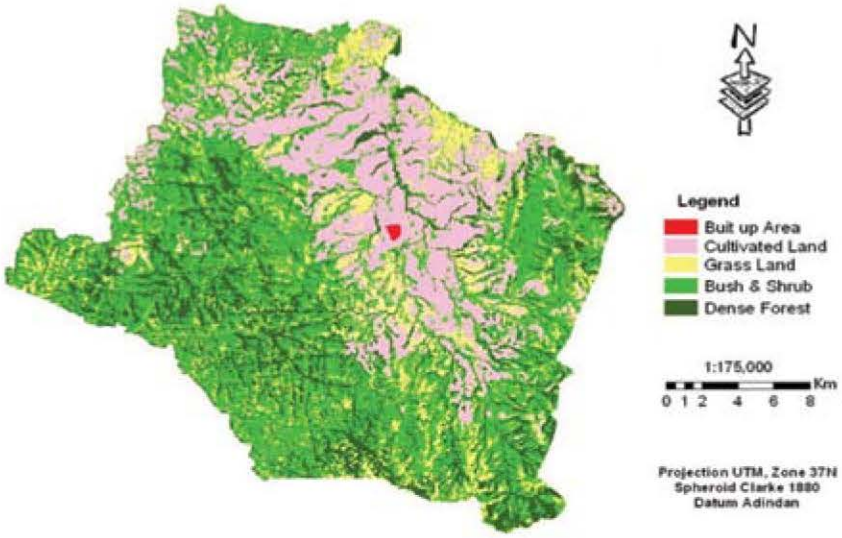

Figure 3: Land-use/land-cover map

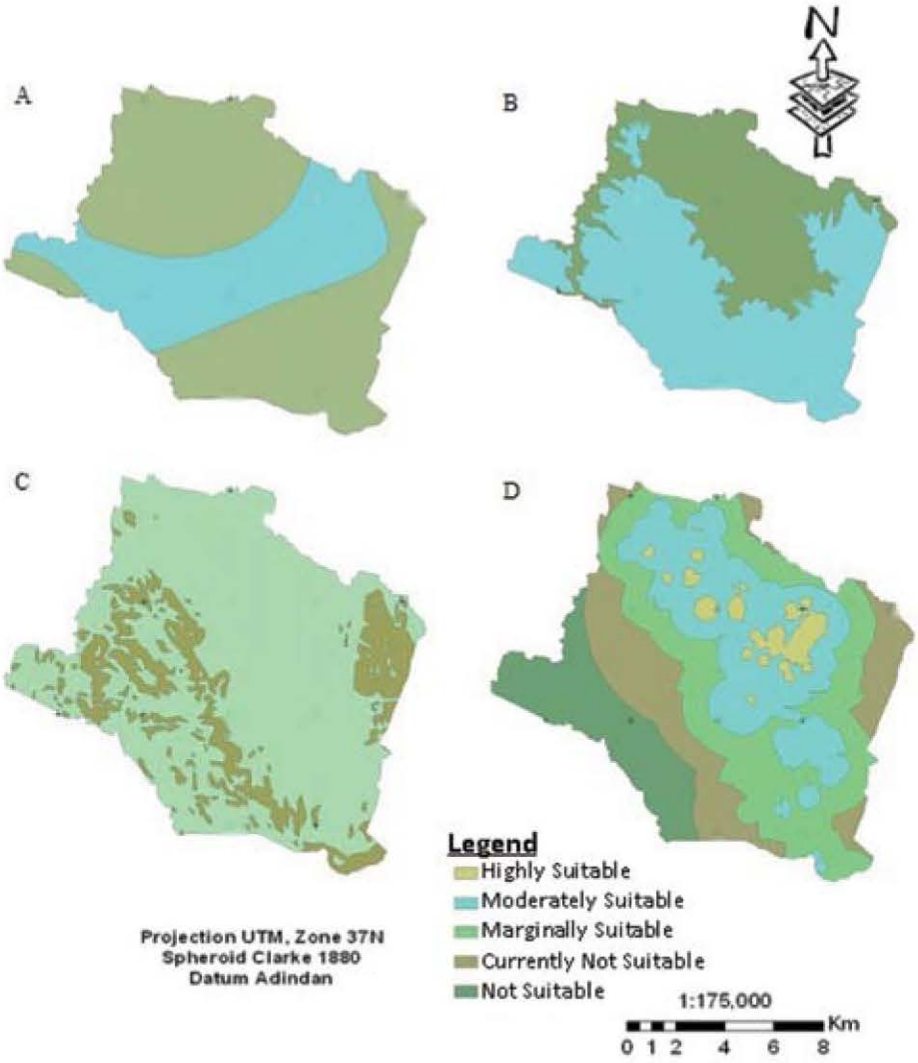

Figure 4: Standardized Suitability Maps of Environmental Factors: (a) Climatic Suitability, (b) Topographic Suitability, (c) Soil Suitability, (d) Infrastructural Suitability

The remaining 150.48 km^2 (24%) of the area with 1000 m–1500 m asl falls within agro-climatic zone marginally suitable for human settlement (due to scanty rainfall and relatively high temperatures coupled with high rate of evapotranspiration).Common weighted topographic analysis revealed that 59.77% (374.76 km^2) of the study area is moderately suitable and the rest of 40.23% (252.24 km^2) as marginally suitable (Figure 4b).

3.1.4 Soil

Soil of the region is mainly of Dystric Cambisol and Lithosol types with the former representing in 99% of the extent, and the latter is confined to the southern extreme representing the remaining 1%. These two kinds of soils possess dominantly vertic properties and are often dark coloured with acidic nature. The soils presented varied physical and chemical properties depending upon their geographical position in the slope. In terms of crop production, though soil in no part of the study area falls within highly suitable category, a great majority (80.44%, i.e., 504.36 km^2) of the region has soils under moderately suitable class and the remaining 19.56% (122.64 km^2) under marginally suitable category (Figure 4c). A large portion of the study area, particularly plains and gentle slopes, has deeper soils rich in organic matter.

3.1.5 Health aspects

As such, no part of the Chawaka district is totally free from malaria threat. About 80% (501.60 km^2) of the study area is under unsuitable category due to risk for malarial incidence. Of the reaming region, 18.00% (112.86 km^2) is marginally suitable and

2.00% (12.54 km^2) is moderately suitable, provided great care is taken.

3.2. Suitability of Socio-Economic Attributes

3.2.1. Proximity to towns

Two towns, namely, Bedele and Nakamte are within a radius of 25 km from Ilu Harer town from which any other town lies at ~67 km. Weighted overlay analysis of proximity of settlement area to any town around is with 100% score under marginally suitable category.

3.2.2. Infrastructure

Infrastructural facilities are not commensurate with the population size in Chawaka district and cost of living is rather high. Only one all-weather road connects Chawaka with Ilu Harer and other towns nearby. Feeder roads are also limited and functional only during dry season. Six elementary and junior level schools cater to the educational needs of children representing insufficient and ill-distributed educational facilities. Similarly, only two health centers exist in the area, but these are not easily accessible. Potable water to resettlers is provided through 51 points (33'bono' based pipe water points and 18 spring water points) mostly concentrated along the road side. Analysis of the infrastructure attribute indicated that 4.68% (29.34 km^2), 27.69% (173.62 km^2) and 30.60% (191.86 km^2) of the region is highly, moderately and marginally suitable, respectively for human resettlement, while 21.07% (132.11 km^2) and 15.96% (100.07 km^2), respectively, are either currently or permanently not suitable (Figure 4d).

3.2.3 Population density

According to the latest report CSA, 2007, Chawaka has a population of 56,106 individuals with 98% representing rural populace and 2% urban populace (from Ilu Harer town, the capital city of Chawaka). Sex ratio (Male: Female) lies at ~112% (mainly due to male dominated migration to new settlements). Age-wise, 50% of the population is in the range of 14-60 years, 43% below 14 and 7% above 60 years signifying the dependency ratio to be 1:1 in the district. Analysis of population density attribute revealed that only 4.47% (28.03 km^2) of the Chawaka district, that too presently inhabitated by farmers (with two or more hectares of agricultural holding) is highly suitable. This was followed by 67.88% (425.61 km^2) and 27.56% (172.80 km^2) areas comprising of less than two hectares per household as moderately or marginally suitable, respectively. The remaining meager area of 0.09% (0.56 km^2) is recognized as currently unsuitable population density.

4. Discussion

The availability of suitable land for resettlement is scarce, and rarely of equivalent quality. Inflexibility of the household responsibilities contributes to the problem (Wang, 2003). It is believed that resettling into communities with cultural similarity can minimize ethnic differences between immigrant communities (Yu, 2004). In the present study of the environmental suitability attributes were compared against each other, weighted and overlaid based on their relative importance for the purpose of finding out the best area for human resettlement in Chawaka district. As reveled from the study, the first four ranks were obtained by the attributes, weather, soil, land-use/ land-cover and topography in that order with scored weights of 0.3089, 0.2298, 0.1369 and 0.1240, respectively. Fifth position was occupied by the socio-economic attribute infrastructure with a scored weight of 0.0885, sixth place by proximity

with a scored weight of 0.0497 and seventh position by population density with a scored weight of 0.0346% while the last bio-physical attribute (health aspect) occupied the last with 0.0276 scored weight. Resettlement of people displaced by the three Gorges reservoir inundation and the adjustment of land-use policy in China resulted in land-use changes, and impacted on the human carrying capacity of the land and the land availability for resettlement (Yan, 2005). The findings of the present study have revealed that a great majority of the Chawaka district was classifies as highly, moderately and marginally suitable classes for human resettlement in terms of almost all bio-physical as well as socio-economic attributes. Thus, only 12.68 km^2 (2.02%) was found to be highly suitable, 412.20 km^2 (65.66%) moderately suitable and 202.12 km^2 (32.32%) marginally suitable for human resettlement purpose (Table 4). New debates have arisen with attempts to move beyond the failings of compensation-based resettlement, for example, thinking behind RwD (resettlement with development) highlights the importance of improving, or at least restoring resettles' livelihoods in a sustainable manner (Dickinson and Webber, 2007). The area qualified as highly suitable (Figure 5) provides the best possible combination of both bio-physical and socio-economic conditions. Compared to other areas, availability of relatively better infrastructure such as health facilities and road network in this area helps in counter balancing the short falls of other attributes noted. The area standing out as moderately suitable possesses all necessary requirements, but for slightly higher temperature controlled by its low topographic elevation dominated by plane and gently sloping land. Similarly, the area that emerged as marginally suitable is having relatively higher topography and unfavorable proximity to towns coupled with not easily accessible infrastructure facilities. Though, proximity of the study area is apparently short (~67 km), in view of the poor road network, insufficient transportation facilities and lack of good communication services, commuting this short distance also turns out to be a negative.

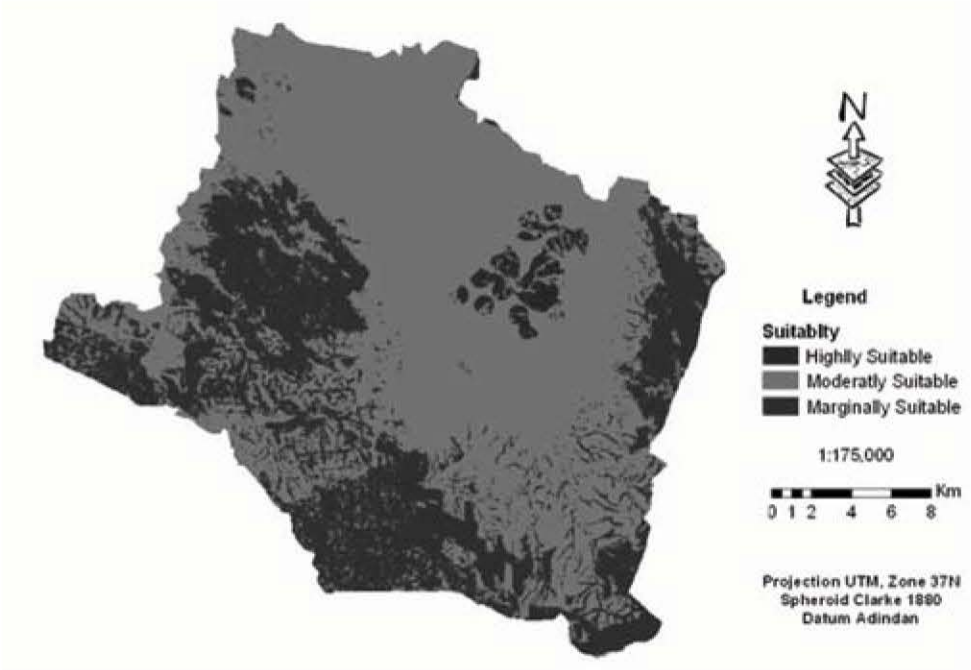

Figure 5: Environmental suitability map of Chawaka resettlement site

Table 4: Overall land area for resettlement

Suitability class	Land area	
	Area (km^2)	Area (%)
Highly suitable (5)	12.68	2.02
Moderately suitable (4)	412.20	65.66
Marginally suitable (3)	202.12	32.32
Total	**627.00**	**100.00**

Ethiopia is conducting a government sponsored resettlement but the site selection is not done on scientific basis. Meanwhile, collective resettlement, in contrast to resettling by individual household, is good for migrants to adapt to the new environment because original neighborhood relationship is carried over to the resettling location (Lu, 2002). GIS analysis can reveal scientific evidence for antipoverty planning and actions (Li and Lin, 2004), and increase efficacy and accountability in poverty alleviation (Wu, 2004), by revealing evidences spatial patterns and concentration of poor people, and offering instrumental support to improve site selection in resettlement planning. Final decision regarding resettlement selection are made based on MCA with all kinds of information, and weighing of a number of factors, this is a process with high spatiality that GIS technology bears its strongest power.

5. Conclusions

Complicated environmental attributes and their complex natural interactions make suitability analysis of a geographical region for human resettlement rather a difficult task. Nevertheless, RS and GIS techniques provide an ideal platform that offers adequate tools for the systematic integration and due consideration of most of the environmental attributes. Therefore, environmental suitability of Chawaka district for human resettlement was analysed during the present study in terms of bio-physical attributes, namely, land-use/ land-cover, weather, soil, topography and health aspects and socio-economic attributes, *viz.*, proximity, infrastructure and population density utilizing the said technologies in combination with MCA. Overall analysis revealed that while a meager one-fiftieth area is highly suitable, as much as two-third area is moderately suitable and around one-third area marginally suitable in Chawaka for resettlement purpose. Since a majority of the area had fallen under moderately suitable category, the same can be chosen as favoured area for resettlement provided infrastructural facilities to safeguard the health of the populace from malarial threat are improved substantially so that the resettlement mission meets with a great success and people are ensured of a reasonably good standard of living.

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