Analysis of urban horizontal expansion and its impact on the surrounding land using GIS and remote sensing: a case of Werabe town

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ABSTRACT

Nowadays, urbanization becomes the widest spreading and expanding event in the world. The issue of urbanization is one of the most important threats for developing countries like Ethiopia. Werabe town, which is found in southern and central parts of the country specifically in the Silte zone south nation nationality people (SNNP) region, is one of the rapidly growing towns at the moment. Therefore, this research is intended to assess the horizontal expansion of the urban and its impact on the use of the surrounding land in Werabe town using a Geographic Information System and integrating socio-economic data. To do this, a Land sat 8 satellite image was used to generate the change detection analysis and all the relevant primary data were gathered. After all, supervised image classification algorithms were applied to determine the available land use types by integrating socio-economic information. Finally, accuracy assessments were done to crosscheck whether the features are accurately classified in the Arc GIS. Based on this, in Werabe town built-up land was increased from 1963.98 ha (12.5 %) in 2009 to 5251, 95 (33.4%) in 2019. Hence, in the study period built-up area was increased by 3287.97ha (20.9%). The forest cover of the study area in 2009 was 3798.27 ha (24.2 %), however, it was decreased to 1358.01ha (8.6%) in the year 2019. Thus 2440.17 ha (15.6%) forest cover was deforested. For agricultural activity, 8833.41 ha (56.2 %) of land was used in the year 2009 but it was altered to 7198.83 ha (45.7%) in the year 2019. Hence from 2009-2019, agricultural land was decreased by 1634.58 ha (10.5 %). Bare land cover in 2009 was 1130.85 ha (7.2%) but it increased by 786.87 (5%) and became 1917.72 ha (12.2%) in the 2019 year. The study evidences that, urban built-up activity is expanding to all the surrounding landmasses, especially it is invading agriculture and forest cover lands of the peri-urban areas. Therefore, to prevent the loss of fertile lands against the ongoing expansion of urban areas, the integration of remote sensing and GIS with appropriate urban land management policy is vital.

Keywords: GIS, image classification, urbanization, land use, land cover

1. Introduction

1.1 Background of the study

Urbanization is defined as an increment in the ratio of population who live in urban areas and the additional physical expansion of already existing urban centres [1]. Urbanization is increasing everywhere, however, the regional difference in the urbanization growth rate is observed. For instance, the African urbanization rate is very low (37.1%) when compared with developed countries like Europe (72.7%) and North America (79.1%) [2]. Even though, urbanization in the developing world low, it progresses much faster than in developed countries, and reaches 3 to 4 % a year. The fast rate of urbanization in the developing world leads to rural-urban migration, economic growth, rapid population growth and technological change [3].

The process of urban expansion takes place both vertically and horizontally which is attributed to high expansion to the land surrounding urban areas. Consequently, it can result in loss of agricultural land, natural beauties and rangelands [4]. A study by [5] projected that by 2030 urban areas will expand by 590,000 square miles to accommodate the needs of more than 1.47 billion people living in urban centres. This massive population growth might be a significant risk for people and the environment over the next two decades [6].

Ethiopia is one of the least urbanized countries in the world, and only 16% of the population is living in 900 urban centres [7]. However, the rate of urbanization is increasing at a rate of 4.4% [8]. The level of urbanization has been only 6 % in 1960, which has increased to11 % in 1984, in 1994 it became 14 %, which was already reached 17.2 % by 2013 and projected to account for 30 % of the total population in the year 2025 [9].

The major contributing causes to rapid urban expansion in Ethiopia are higher natural population growth, rural to urban migration and spatial urban development [10]. The higher horizontal expansion of urban zones in Ethiopia leads to greater demand for land around the peripheral areas for different buildings, and this, in turn, causes loss of agricultural land, natural beauties and rangelands [11].

Werabe town, which is found in SNNP of Ethiopia, is one of the fast-growing and expanding urban centres in the country. Its expansion is out warding to the peripheral land at the expense of arable and agricultural lands due to factors such as building up practice, proximity to the national market and accessibility for various types of infrastructures [5]. As a result of this process, a huge amount of hectares are being changed into urban land uses and this has various impacts on the environment and livelihood of peri-urban farmers.

So far, researches on urban expansion have been conducted in different towns in Ethiopia, none has been done in Werabe town of Silte zone. Furthermore, the extent, magnitude and potential impact of urban horizontal expansion of Werabe town has not been investigated. Therefore, this study tried to analyze the expansion of Werabe town using remote sensing and GIS techniques from 2000 up to2019. The specific objectives that study addressed were, therefore:(1)to show the LU/LC change of the study area (2)to assess the horizontal expansion of Werabe town (3)to identify the major trigger factors for horizontal expansion of the town (4) to evaluate the impact of urban growth on the surrounding land use. Consequently, the finding of this study may help to minimize negative impacts of urban expansion in economic, social and environmental impacts, to bring mutual development and symbiotic integration of the rural and urban life that foster social and economic development. The finding of this study will also be significant in providing realistic information and initial input for urban planning experts, governmental and non-governmental organizations. Hence decision-makers can take into account the situation of the urban planning process. Apart from this, the finding in this study will help academicians as baseline information for other related research topics.

2. Review literature

2.1. Urbanization and growth rate in Ethiopia

The history of towns developing in Ethiopia goes back to the Axumite Kingdoms of the 14th c, when Axum, the first political and religious centre in the north of the country, was established. Even though the government failed to build a well-organized and large size urban settlement, it was accounted for the establishment and growth of several towns, especially, in north Ethiopia [12]. For instance, Axum, Lalibela, and Gondar were found to be urban centres that served as capitals of the country in the 4th c, 11th c and 17th c, respectively [13].

Despite this long urban history, Ethiopia remains one of the least urbanized countries in sub-Saharan Africa [14]. Nowadays, the urban growth rate in Ethiopia is dramatically changed [15]. On average, the annual urbanization growth rate from1960-1991 was 4.8 % which grew to 5.8 % from1991-2000 [16]. It reached 17.2 % in 2013, and also projected to reach 23% in 2030 [17]. Besides this, it is estimated that the World's, African's and Ethiopian's urban population growth rate by 2025 will reach 58%, 52%, and 32% respectively (Webster, 2005) as cited by [18]. This growth rate makes Ethiopia among the 23 rapidly urbanizing countries of the world [19]. However, the level of urbanization has significant regional variation. For instance, urbanization growth rate of Addis Ababa is 28.4%, Amhara 17.32%, Oromia 17%, SNNP 15.2%, Tigray 15.2% and Gambela 9.62% respectively [20].

2.2. Causes of Urban Expansion

There is debate among scholars about the cause of urbanization expansion. Most of the rapid urban expansion to the neighboring rural environment in developing nations is caused due to in-migration (both rural-urban migration and urban-urban migration) [21]. Rural communities are very much dependent on small farmlands, which become difficult to improve one's living beyond basic subsistence's. To such communities, their farm is dependent on unpredictable conditions such as drought flood and pestilences. As a result, the people decide to migrate to urban areas

The other cause of urban expansion is induced by economic advancement, urban clearance and/ or industrialization [22]. Hence, places or sites that are adjacent to urban areas might be needed for social, economic, industrial and communication, road construction and other infrastructure and investment [23].

Furthermore, factors that contribute to the growth of urbanization in Ethiopia include the establishment of the central government, the introduction of modern business and contact with the outside world for the establishment of a large number of industries and organized farms [13].

2.3 Negative impacts of urban expansion

Urbanization negatively affects peri-urban areas in different ways. As pointed out by [24] uneven urban expansion will occupy considerable valuable farmland around urban centres, which becomes a source of conflicts with the farmers who are displaced from their farmland. Hence, urban expansion leads to the loss of agricultural and forest land with valuable ecological functions. The problem of urban expansion towards agricultural land is not only due to lack of free land but it is also due to lack of appropriate government policy and strategy.

According to [25], urban expansion led to a loss of farmland and displacement of the households who had been involved in farming activity. Urbanization is a cause for the decline of natural assets and mainly agricultural land, causing inadequate food, poor nutrition and poor health.

3. Materials and Methods

3.1 Description of Study Area

Werabe town is situated northwest of the capital of the southern regional state, Hawassa at 200 km and 173 km far from Addis Ababa [26]. Astronomically, Werabe lies approximately between 70 48'04" and 70 55'15" N latitude & from 380 08'42" to 380 13'42" E longitudes as a coordinates system. As far as the relative location concerns, it is bordered by peasant association Aratbermukarie in the north, Albazar in the southwest, Garmama in the east and Fugie in the south. Naturally, the town is bordered by Wello mountains in the southwestern, Mitija mountain in the southeastern [27]. The report of [27] also indicated that in 1994 the population of Werabe town was 690 which was grown to 26,670 in 2018/19.

3.2. Data types and source

The study was relying on both primary and secondary data. Primary data were collected using a questionnaire from 145 households and focus group discussions with elder people who have been living in the town since 2000. A total of 12 residents, six from each sub-city were involved in focus group discussion as key informants about the historical development of the town and other related socioeconomic consequences, as well as about the factors that contributed to urban expansion. Besides, GPS readings have also taken in the field to verify built-up areas and to digitalize kebeles' boundaries of the study area.

Secondary data were collected from Werabe town municipality administration office, land administration office, finance and economic development office of annual and quarterly reports. Furthermore, the Topographic map, quick bird satellite image, and aerial photograph were acquired from the Ethiopian mapping agency. Primary data was used as supportive evidence with secondary data during data analysis and interpretation

3.3 Methods of data analysis

The primary data obtained using FGD from elder person community members selected in the pre-urban evicted farmers were analyzed qualitatively. Concerning the data gathered from a household survey the pre-coded questionnaires were processed, managed and analyzed by using the Statistical Package for Social Sciences (SPSS) software and Micro-soft excel program. Variables such as sex, age, households size, education status, their attitude on the effects of urban expansion on their farmland and livelihood were analyzed using descriptive statistics mainly percentage and mean as well as graphs.

The land use and land cover of the study area was generated using maximum likelihood classification algorithms. The maximum classification algorithm assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood). The acquired land use statistics data were presented and analyzed by using tables, figures, charts and reports. Visual interpretation of various environmental features of the study area was done based on the visual elements or characteristics of the satellite image, i.e. tone, texture, shape, pattern, shadow, association and aspect of the features with the support of field verification of each land use/land cover features.

3.4 Calculations

Accuracy assessment

To assess the classification accuracy, a confusion matrix was used Table SM1. The confusion matrix indicates the nature of the classification error and used in many other research works [28].

To get the overall accuracy:

$$\frac{total\ number\ of\ correctly\ classfied\ pixels\ (diagonally}{Ttal\ number\ of\ reference\ pixel} * 100$$

Hence; **18/20*100**

<u>= 90</u>

I. User Accuracy:

$$\frac{Number\ of\ correctly\ classfied\ pixels\ in\ each\ catagory}{total\ number\ of\ pixels\ in\ that\ catagory\ (the\ row\ total)} * 100$$

Therefore;

Built up area 5/5*100=100

Forest 4/5*100 =80

Agriculture 5/5*100 =100

Bare land 4/5*100=100

II. Producer accuracy:

$$\frac{Number\ of\ correctly\ classfied\ pixels\ in\ each\ catagory}{total\ number\ of\ reference\ pixels\ in\ that\ category\ (the\ column\ total)} * 100$$

Hence;

Built-up area 5/6*100=83.33

Forest 4/5*100=80

Agriculture 5/5*100=100

Bare land 4/4*100=100

III. Kappa Coefficient

$$\frac{KC = (TS * TCS) - \sum(Column\ total * Row\ total)}{TS^2 - \sum(column\ total - row\ total)} * 100$$

Where TS = total sample and

TCS = total correctly classified samples

Based on this formula;

(20*18)- s(5*5)+(4*5)+(5*5)+(4*5)/400-(5*5)+(4*5)+(5*5)+(4*5)*100

360-90/400-90

270/310*100

KC = <u>87.1</u>

The overall accuracy and kappa coefficient is 90% and 0.87 respectively. According to [29], the agreement criteria for Kappa statistics (K) was defined as: poor when K<0.4, good when 0.4<K<0.7 and excellent when K>0.75. Thus, according to these agreement scales, the LULC classification for 2019 in this study denotes good.

Results and discussions

This chapter presents the main findings of the study concerning the horizontal expansion of urban and its impact on the other land-use system depending on the land sat satellite image integrated with socio-economic data.

4.1 Demographic and socio-economic profile of the respondents

A socio-economic survey was undertaken and out of 145 respondents' 135 were male and the remaining 10 were females' households table 3. The age of respondents is categorized as: below 20 years, 20-30 years, 30-40 years, and 40-50 years, 50-60 years and above 60 years of age. More than half of the respondents (76) lie under the 40 -50 years age category and the least respondents' number was recorded in the range of above 60 years old table 1.

Concerning the education level of respondents, (46) sample households (31.7%) attended grades 5-8. The remaining (17.2%), (24.2%), (20%), (5.5%) and (1.4%) of the respondents were illiterate, able to read and write, attended grade (1-4), attended grade (9- 12) and had attended tertiary education (college and university) respectively Table 2.

Table 1: Age and Sex of the respondents

N o	Age	Sex			Per cent
		Male	Female	Both sex	
	below 20 years	6	-	6	4.1
	20-30 years	10	-	10	7
	30-40 years,	30	4	34	23.4
	40-50 years,	70	6	76	52.4
	50-60 years	15	-	15	10.3
	60 years above	4		4	2.8
Total		135	10	145	

Source: Field Survey, 2019

Table 2: Educational level of respondents

Educational level	Frequency	Percent
Cannot read and write	25	17.2
Read and write	35	24.2
Grade 1-4 class	29	20
Grade 5-8 class	46	31.7
Grade 9-12 class	8	5.5
Above grade 12 class	2	1.4
Total	145	100

Source: Field Survey, 2019

Most farmers are not well educated and skilled rather depending on their agricultural production, it is understood that people without basic qualifications or skilled are unable to compete and get a job in the labour market [30].

4.2 The land use /land cover distribution of Werabe town (2009 and 2019)

The land sat 7 ETM+ was used enables to generate the required land use and land cover for the study area obtained from Ethiopian Map Agency. Before the classification algorithm process, all the necessary steps of image processing were conducted such as layer stacking the seven bands

into one layer as it is helpful to identify the different land cover features easily and for other useful operational objectives. Moreover, image substituting was conducted to delineate the target to make it ready for the classification system. After all, the LULC of the study area was classified using supervised image classification techniques.

4.2.1 Image analysis and interpretation

As it is depicted in fig 1 below, the land use types of the study area were classified into four main land-use classes namely, forest land, agricultural land agricultural and bare space land. To make use of the multitude of digital data available from satellite imagery, it must be processed in a manner that is suitable for the end-user. This processing includes categorizing the land into its various types. This is done by the use of a vector layer containing training polygons. After supervises classification, it was reclassified, and values were calculated again using the Arc GIS.

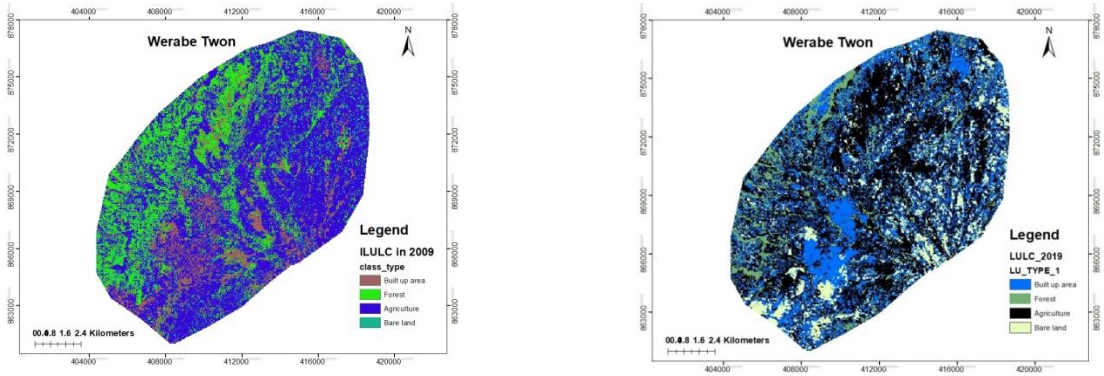

Figure 1: (a): Land use map of Werabe town (2009) (b): Land use map of Werabe town (2019)

4.3 Land-use types at different periods in Werabe town

The following table shows the land use distribution of the study area in percentage, meters, and hectare (ha).

Table 3: Land- use proportions of the study area in (2009)

No	Land use type	Count(Pixel values)	Area in m² (1 pixel = 30m*30m/900m²)	Area in hectare (1 ha = 10,000m²)	Area in (%)
1.	Built up	21822	19639800	1963.98	12.5
2.	Forest	42203	37982700	3798.27	24.2
3.	Agriculture	98149	88334100	8833.41	56.2
4.	Bare	12565	11308500	1130.85	7.2
5.	Total	174739	157265100	15726.51	100

As table 3 above shows, the study area has a total of 15726.51 ha of land features. Ended, the area has different land-use types with different proportions, namely as built-up area, forest, agricultural land and bare land which has a land-use value of 1963.98 (12.5), 3798.27 (24.2), 8833.41 (56.2), and 1130.85 (7.2) respectively. According to the above table and map, greater parts of the study area were covered by Agricultural land use (8833.41 hectares or 56.2 %) in 2009. As table 3 shows us, the study area was dominated by agricultural lands in 2009 as it is cross-checked by the respondents.

. Table 4: Land use types of the study area in different units (2019)

No	Land-use type	Count(Pixel values)	Area in m² (1 pixel = 30m*30m/900m²)	Area in (ha)	Area in (%)
1.	Built-up area	58355	52519500	5251.95	33.4
2.	Forest	15089	13580100	1358.01	8.6
3.	Agriculture	79987	71988300	7198.83	45.7
4.	Bare land	21308	19177200	1917.72	12.2
5.	Total	174739	157265100	15726.51	100

Table 4 above shows that the study area contains four major land-use types including built-up area, forest, agriculture and bare land with a value of 5251.95 (33.4%), 1358.01 (8.63%), 7198.83 (45.8%) and 1917.72 (12.2%) respectively. Based on table 4 even though the majority of the study area is covered by agriculture, but it is changed from 57% in 2009 to 45% in 2019 due to rapid urban expansion at the cost of agricultural lands.

4.4 Land use/land covers change of Werabe town

Table 5 shows the land use land cover of the study area in percentage, meters, and hectares (the resolution of the pixel value = 30m *30m) (900m².)

Table 5: Land use /land cover change of Werabe town (2009 and 2019)

year		2009		2019		Change (2009 to 2019)	
	Land use type	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
1.	Built-up area	1963.98	12.5	5251.95	33.4	3287.97	20.9
2.	Forest	3798.27	24.2	1358.01	8.6	-2440.17	-15.6
3.	Agriculture	8833.41	56.2	7198.83	45.7	-1634.58	-10.5
4.	Bare land	1130.85	7.2	1917.72	12.2	786.87	5
5.	Total	15726.51	100	15726.51	100		

The main LULC, under the study periods (2009 and 2019) was built-up areas, forest cover change, agricultural land and bare land. Built-up land in the study area has increased substantially during the study years. It occupied 1963.98 ha (12.5 %) of land in 2009 and raised to 5251, 95 (33.4%) of land in 2019. Due to the expansion of the town an additional 3287.97ha (20.9%) was used for various types of built-up areas. The forest cover of the study area in the year 2009 was 3798.27 ha (24.2 %) but it was changed to 1358.01ha (8.6%) by the year 2019. Therefore due to urban expansion 2440.17 ha (15.6%) of the forest was cleared mainly for residential and commercial purposes. For agricultural activity, 8833.41 ha (56.2 %) of land was used in the year 2009 but it was altered to 7198.83 ha (45.7%) in the year 2019. Hence from the

2009-2019 study times, agricultural land was decreased by 1634.58 ha (10.5 %). Bare land cover in 2009 was 1130.85 ha (7.2%) but it was changed to 1917.72 ha (12.2%) in the 2019 year. The bare land cover increased by 786.87 (5%) between 2009 and 2019 years.

4.5 Causes and consequences of Werabe town expansion

Information obtained from indigenous peoples of the town and Silte zone land administration officials indicates the cause of urban expansion was: migration from other parts of the country which accounts for 38.6 %, followed by rural-urban migration 31%, infrastructure accessibility15.8%, demographic dynamics (high birth & low death rate 7.6%, and reclassification of the former rural settlement into new urban settlement 7% Table SM 2.

Response of the FGD indicates many people migrate from the rural to urban areas to share the advantage of living in the town areas like accessing better jobs. The interviewed zone officials also confirmed that expansion of Werabe town enables the creation of job opportunities, obtaining better services like education, transportation, health, electricity and communication. The development of various infrastructures in the peri-urban areas also improves the accessibility of the areas to the urban centres, which in turn strengthen the social interaction of the peri-urban communities with urban society. Therefore, this finding shows urban development brings socio-economic opportunities to the local communities.

Earlier studies also support the finding of the current research. For instance, a study in Malaysia indicates urbanization in Malaysia creates job opportunities to farmers such as a technician, mechanic, and security guard at factories. In addition to creating more job opportunities, urban development in the peri-urban areas also widens the market for the informal job sector [31].

Research by Simon [32] indicates the expansion of good network infrastructure encourages many people to set up small shops and restaurants along both sides of the road. Another study by [33] also states that commercial activities along the road in the periphery of the urban core in Kenya provide farmers with outlets to sell products or to purchase what is needed for farming. These activities also enable peri-urban dwellers to access food supplies and other necessities without travelling to the urban core.

Even though urban development provides more economic opportunities to the local communities, demand for urban land in the study area has increased, resulting in the conversion of forest and agricultural land mainly for built up and for other infrastructural development.

A study conducted in Bahir Dar city of Ethiopia shows built-up land was increasing by 38% (634 ha) in the period 2000 to 2016 [21]. Hence, the land-use change would result in numerous negative consequences such as loss of prime agricultural farmland. Another study by [34] also showed a large productive agriculture area in Penang was converted due to the construction of new infrastructural development or built-ups. Thus, due to rapid urban expansion agricultural land has become scarce, and many people moved to another area.

Urbanization in the study area intensifies farmers engagement in non-agricultural activates, which in turn, forces them to leave farming practice through time. Consequently, the major source of their livelihood has been profoundly changed. A finding by Raddad [35] also indicates farmers comparison between agricultural and non-agricultural activates worsen the existence of agriculture. The current study, therefore, concludes farming and related activities might disappear soon if no serious action is taken by planners and policymakers. The decline in agricultural activities not only threatens food security but also causes stress on the ecological condition at the micro and macro level.

Conclusions and recommendations

Conclusions

The main objective of the study was to examine the expansion of urban and its effects on the surrounding areas of Werabe town, Ethiopia. Accordingly, in the study area, there is an observable change of land use/land cover from 2009 to 2019 years. During the study years, built-up land was increased from 1963.98 ha (12.5 %) in 2009 to 5251, 95 (33.4%) in 2019. Hence, for the built-up area, 3287.97ha (20.9%) of peri-urban land was used due to the town horizontal expansion. The total forest cover of the study area was 3798.27 ha (24.2 %) and 1358.01ha (8.6%) in the years 2009 and 2019 respectively. The result showed forest cover was declined by 2440.17 ha (15.6%). Agriculture land was decreased by 1634.58 ha (10.5 %). The bare land cover was increased by 786.87 (5%).

In the study area, mainly migration, access to infrastructure facility and demographic dynamics were the causes of urban expansion resulted in high demand for urban land. With an increased demand for urban centres, more forest and agricultural land from the peri-urban area is required. As a result of a sharp decrease in agricultural land, it threatens the livelihood of the farming communities.

Therefore, to prevent the loss of agricultural lands against the rapid horizontal expansion of urban, effective land use and land management strategies are strongly advocated. Furthermore, a sound policy at the local level is urgently needed. This policy should give attention to public participation, not only to facilitate approval of the plan but also to help oversee the impact of the implemented development plan on the local communities.

Recommendations

Generally, the study shows that urban expansion becomes the most threat for the study areas since it becomes expanding at the coast of other land-use types. Therefore, the following recommendation measures need to consider.

The integration of remote sensing and GIS with appropriate urban land management policy is vital for effective land use. Hence, it is advisable for the conceded bodies to use these technologies on future urban development plans to reduce the impacts of urban horizontal expansion on various land uses/covers.

To reduce the extreme loss of agriculture, applying vertical urban expansion is recommended.

Besides this, greater attention should be given to the agricultural land; hence the concerned body should have prepared a local development plan with high involvement of the local community.

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