An Automated Approach for Partitioning of Inhertited Land: A Case from India

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Keywords: Land partitioning, land division, value map, automated partitioning.

SUMMARY:

Agricultural land is a valuable resource for reasons like food security, rural economy and development, and resulting prosperity. It is also a symbol of status in rural communities. Consequently, the agricultural land is essentially divided amongst prospective owners in each generation according to the inheritance laws. The division ensures security to next generation, independence, social and legal rights, and individual identity to the owners. Generally, it is observed that the partitioning in case of inherited land is done on the basis of area. This ignores many additional facilities and factors like soil fertility, irrigation sources, storage sources, access to roads and market places etc. In such cases, partitioning may sometimes be reason for dissatisfaction and leads to conflicts. In the view of this, this paper presents a new approach that considers all relevant factors, namely – soil fertility, fixed structures, proximity to marketplace, access to road, and irrigation facility. The approach considers location of these factors and model their effects to create value maps of land for each factor. Furthermore, the approach aims to perform value based automated partitioning to create parcels of specific values. To implement the proposed approach, relevant features are first vectorised on a map of a study area. Value maps for each feature is derived by spatial interpolation functions on raster map. Combining all value maps derives total value map and calculates total value of the land. Based on the total value, the approach partitions given land into required number of parcels having equal values by the automated algorithm. Results ensure that the adopted approach can create new parcels of equal values with straight inter-boundaries and rectangular shapes. Area allocation by partitioning algorithm is directional, which is influenced by locations and spatial variations of facilities. Multiple factors at one side of land dominates over individual feature. Moreover, linear features varying in one direction influences partitioning more than point features varying in two directions. In future, authors envision to derive weighted value of a land for partitioning to encompass possibilities of large variations in values of each factor. Moreover, it would be interesting to implement the approach on an irregular shaped agricultural land and parcels.

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1. INTRODUCTION

For countries like India, agriculture land is not only a resource for survival but also it drives the economy for all sections of society. In rural areas, income generated from agricultural land brings prosperity and attracts development. Land is also seen as a status symbol in rural areas. Over generations, the agricultural lands are divided as per prevailing inheritance laws. Despite land fragmentation creates many issues, it offers some advantages as follows:

i. **Security:** Having ownership of agricultural land gives a sense of security. A greater sense of security leads to stability and peace in life and society.
ii. **Social and legal rights:** Social and legal issues generally arise if the land remains undivided among prospective owners. However, after division, a landowner always has rights for all social and legal matters related to transfer of title for the current generation, sell or purchase, and agricultural income. This leads to fewer conflicts and subsequent court proceedings. So partitioning preserves peace at both community level and individual level.
iii. **Independence:** When sons and daughters of deceased ones receive equal rights on the land, it bridges the economic gap in society and villages. Not only that, it is especially important for females for their financial security and independence.
iv. **Identity and status:** Individual ownership also gives a better identity and status in rural areas.

With increasing population, land subdivision is inevitable (Niroula and Thapa, 2005). Partitioning of inherited land imposes complexities for division and sharing of facilities like sources of irrigation (canals and wells), connectivity and proximity to the main road, soil fertility, fixed properties on the land (shed) etc. These facilities are either scattered (wells, connectivity to road, shed) or spatially varying (soil fertility). Conventional approach of partitioning assumes uniform soil fertility and divides a land equally by area among prospective owners such that each owner should have at least one of the available facilities. At times, as an alternate, owners prefer to opt for multiple and smaller parcels segregated at different locations across the land to avail equal advantages of each facility. With either way of area based partitioning, most of the times, prospective owners remain unsatisfied as the area based partitioning raises social and economic conflicts (Bentley, 1987; Niroula and Thapa, 2005). Apart from that, the area based partitioning approach generally ignores additional factors like distance from marketplace.

Different studies are available in state-of-the-art literature on land partitioning. Table 1 presents relevant details of these studies.

Table 1: Literature on land partitioning

Purpose of partition	Country of study	Reference
Land consolidation	Cyprus	Demetriou et al. (2012), Demetriou et al. (2013)
	Netherlands	Buis and Vingerhoeds (1996); Rosman (2012)
	Turkey	Hakli et al. (2016); Hakli and Harun (2017); Hakli (2019)
	Spain	Tourino et al. (2003)
Designing urban layouts	Australia	Wickramasuriya (2011)
	City of San Marcos, Texas, USA	Dahal and Chow (2014).

Although above mentioned studies (in Table 1) performed automated partitioning of land area, these were mainly aimed at either land consolidation or designing urban layouts. On the other hand, partitioning of inherited land imposes different set of conditions, which are not addressed in state-of-the-art literature. Therefore, there is a need to design a new approach of automated partitioning of inherited lands to address different needs and study areas. We propose a new approach that focuses on subdivision of inherited lands having facilities (like irrigation sources, soil fertility, distance to market place etc). The proposed approach, at first, considers the factors and derives spatial values of land caused by each of these factors. According to the value, the land is equally divided by value among the prospective owners. This condition would ensure that the prospective land owners receive equal distribution of value in a parcel.

The paper is organized into five sections. After the introduction and literature on partitioning in this section, second section describes materials and methodology. Third section demonstrates the use of partitioning algorithm for value based partitioning on a case study area. Results and discussion are presented in fourth section. Finally, section five concludes the paper and highlights the possible scope of future work.

2. MATERIALS AND METHODOLOGY

In this section, a methodology that considers prevailing rules and regulations and creates parcels with equal value using an algorithmic approach is presented. The proposed method first evaluates the value of an area, followed by partitioning using an automated algorithm.

The proposed method of land partitioning consists of three steps. The first step creates value maps for different thematic maps of an area. Each pixel value in the map defines the value of the property at that location. The second step combines all maps to create a combined value map. The third step uses the total value map to divide the land into the required number of parcels of equal value. The approach adopted in this paper is shown by figure 1.

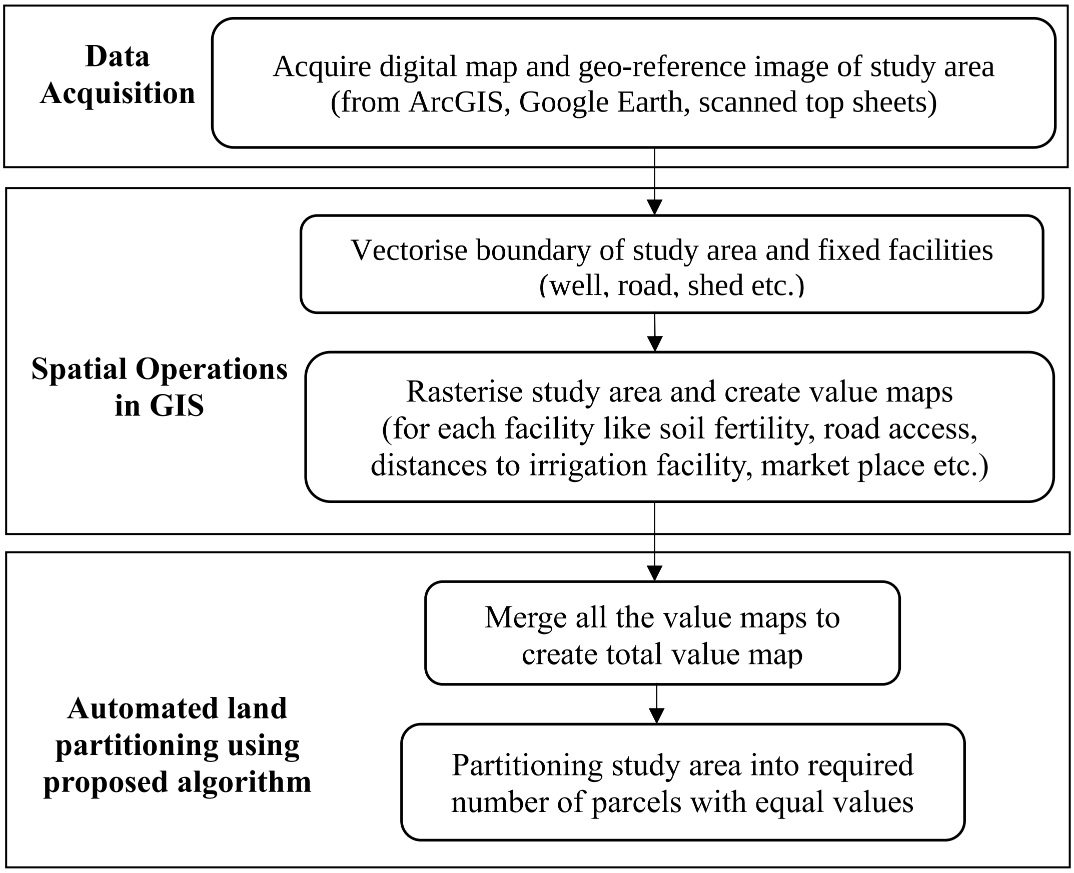


Figure 1. Flowchart for proposed approach of value based automated land partitioning

2.1. Creation of value maps

This step creates the value maps for different properties of the land. The entire area is divided into grids, and each grid represents the value of the property at that position. The properties are soil fertility, connectivity to the road, distances from the marketplace, fixed structures on the land, and irrigation facility. Figure 2 presents a land parcel, which is to be divided in four prospective owners. All the properties and procedure for finding the respective value maps are explained as follows:

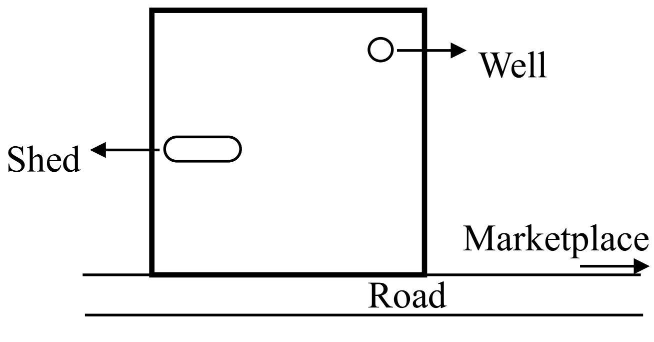


Figure 2. Area for demonstration

2.1.1. Soil fertility (Lf): Normally, fertility of land does not change significantly in an area. A part of the land may be rocky or may remain barren for a significant amount of time. This information can be obtained from soil testing as well as experienced land evaluators. The value of fertility varies from 1 to 10. A barren land is represented by 1 and most fertile land is represented by 10. Figure 3 shows the change in fertility for the demonstration area.

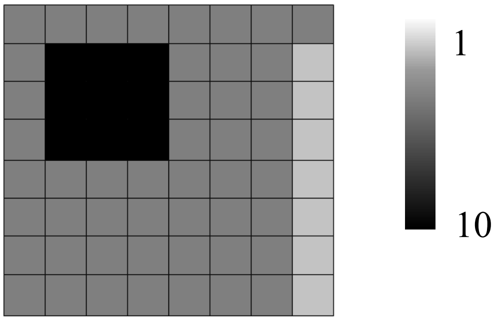


Figure 3. Value map for land fertility

2.1.2. Connectivity to the road (Rc): Most of the land parcel has a single road connecting to the major road in an area. Consequently, a land is partitioned in perpendicular direction to the road so that each parcel can have access to the road with minimum distance. However, for a parcel nearest to the road, pixels have easier access than pixels of other parcels. Other parcels require either a new road that connects the parcels to the main road or accessing road may cause inconvenience to other owners. Hence, the area around the connecting road is valued higher than the surrounding area. The column of pixels having road access will always have advantage and so they are valued higher than other pixels. The value of land with respect to road accessibility also varies from 1 to 10. The value map for road connectivity for the demonstration area is shown in figure 4.

Figure 4. Value map for road connectivity

2.1.3. Distance from the marketplace (Md): The value of a land also depends on the distance of the land from the marketplace. The land close to the marketplace has a higher value as compared to the land away from the marketplace. Like other properties, this is also valued on a scale of 1 to 10. The nearest land pixel to the marketplace is valued as 10, and then it gradually decreases as inversely proportional to the distance from the marketplace. Figure 5 indicates the value map for marketplace distance.

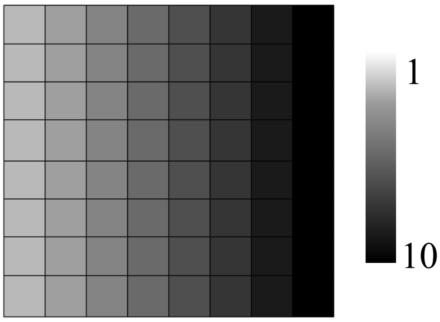


Figure 5. Value map for distance from market

2.1.4. Fixed structures on the land (Fs): If there exists a structure and occupy area on the land such as a shed used for storing equipment, harvested crop, or place of worship, it is valued more as compared to the other parts of the land. As the partitioning is done perpendicular to the road, the column containing fixed structure only has the advantage to access and use it. Hence, the fixed structure is considered as point feature and pixels containing the structure are assigned highest value equal to 10 and other pixels are assigned 0. For demo area, value map is depicted in figure 6.

2.1.5. Irrigation facility (If): The area around the irrigation facility is given value higher than the area away from the irrigation facility. This is due to the reason that a person away from the irrigation facility will have to make arrangements to irrigate his/her land. The value varies inversely proportional to the distance from the irrigation facility as indicated in figure 7.

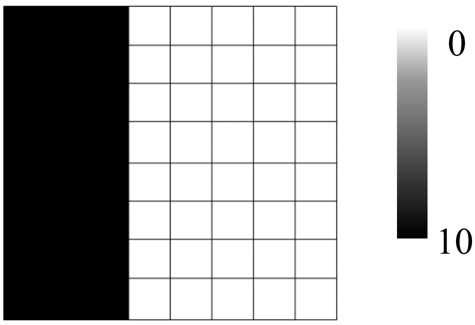


Figure 6. Value map for fixed structure on land

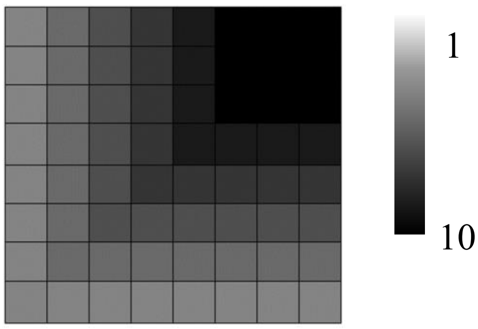


Figure 7. Value map for irrigation facility

2.2. Derivation of total value map

All the maps obtained from the first step are combined to form a single map of total value. To create this total value map, the average value of all value maps is calculated for a pixel using equation 1.

$$V_{i,j} = \frac{Lf_{i,j} + Rc_{i,j} + Md_{i,j} + Fs_{i,j} + If_{i,j}}{5} \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where N_x and N_y are number of pixels in x and y directions of on map for an area, respectively. $V_{i,j}$ represents total value of pixel (i, j). The total value map for the demonstration area is shown in figure 8.

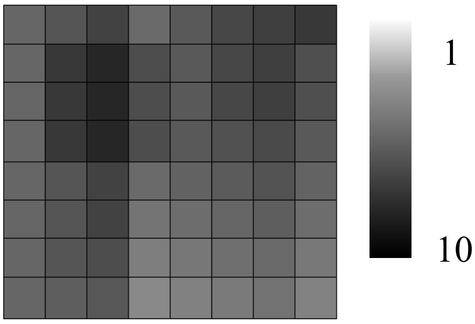


Figure 8. Total value map of land

2.3. Partitioning of land

This step first calculates total value of entire land as summation of total value of each pixel, as shown by equation 2.

$$V_l = \sum_{j=1}^{Ny} \sum_{i=1}^{Nx} V_{i,j} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where, V_l represents the entire value of the land, i.e. total value map summed over total number of pixels $(= Ny\ Nx)$. Next, the value for each owner is calculated by dividing the total value of the land by the number of prospective owners (P_o) as:

$$V_p = \frac{V_l}{P_o} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

After calculating the value of land for each owner, partitioning is performed. Starting from one side of the land, the area is increased successively by a column of pixels in each iteration till the value of occupied area is equal to V_p. This area is allocated to the first owner. This process is carried out until all the land is divided into the required number of parcels.

In the present case, the total value of land is obtained as 375.2 units (from figure 8). This calculates value of land for individual owner as 93.8 units. To assign this value, the algorithm starts from one side and pixels are added column wise until value is equal to 93.8 units. Then all the pixels till this stage are allocated to the first land parcel. The process is repeated till all the owners are assigned land parcels. The demo area is divided amongst three owners as shown by figure 9. In the figure, land values allocated to parcels 1, 2, 3 and 4 are 94, 97.8, 89.8 and 93.5, respectively. The small variation is due to limitation of algorithm that it assigns pixels in column wise manner successively to parcels from left.

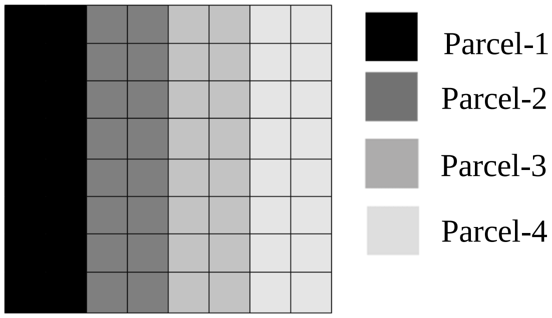


Figure 9. Partitioned land parcels

3. CASE STUDY

The method proposed here is used for land partitioning of an agricultural land in Bhosare village in Maharashtra state of India. The location and detailed map of the agricultural land (study area) are shown in figures 10 and 11, respectively.

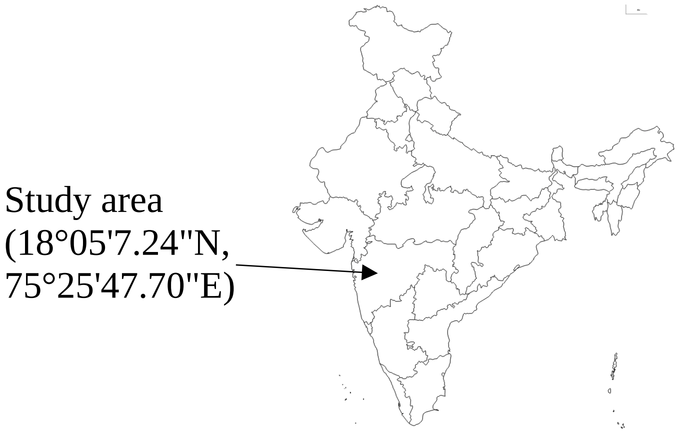


Figure 10. Location of the study area in Bhosare village (India)

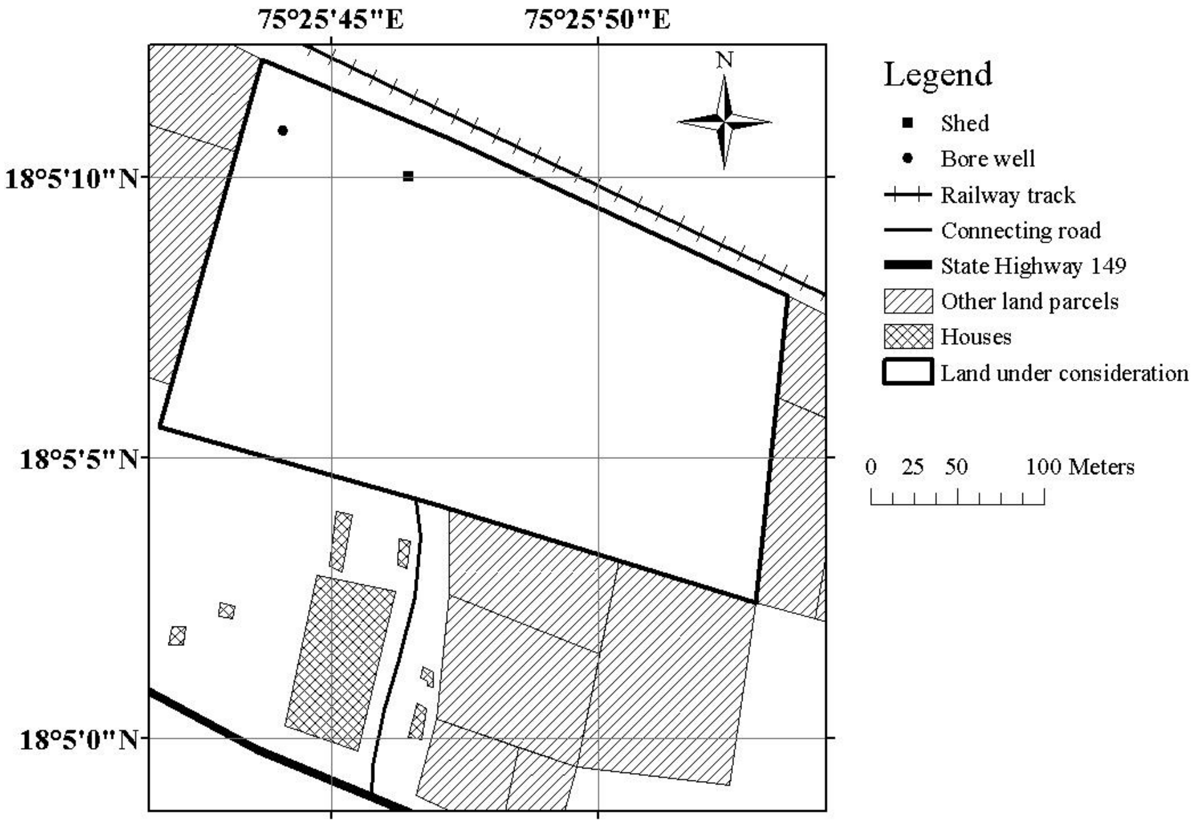


Figure 11. Map of study area

The study area occupies 61644 m^2 area and is characterized by black cotton soil. As shown in figure 11 above, the agricultural land lies between a railway track and a State highway. A road of 2 m width and approximately 160 m in length connects the entire land to the State highway. The land is surrounded by land parcels in the East, West and South directions. A marketplace is situated at distance of 2 km in West direction (not shown in figures). The study area contains one bore well in the North-West corner and a shed near to boundary in North.

The land is to be divided into 4 equal value parcels. To implement the proposed method in raster format, hard copy of local map of the area is scanned at 200 dpi and georeferenced. The georeferenced map is rasterized at a pixel size of 20 cm on ground. Except for shed (fixed structure), values of remaining properties are normalized and mapped on the scale of 1 to 10, where 1 and 10 indicate minimum and maximum values of property, respectively. For shed, the value map is mapped between 0-10 as explained above. Normalization provides a unit less scale for each value maps and allows integration of all value maps to generate total value map. Following description explains modelling of soil fertility, road access, distance to marketplace, shed (fixed structure), and irrigation facility.

Soil fertility: The land has maximum fertility in North-West part. It is modelled as point feature, i.e. maximum at the North-West corner and it varies linearly with distance in all directions. As result, the soil fertility is minimum equal to 1 at remaining three corners of the land as shown in figure 12.

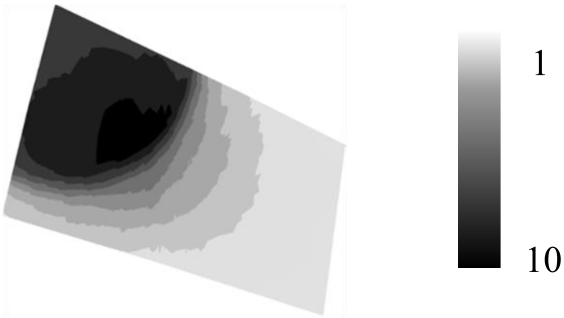
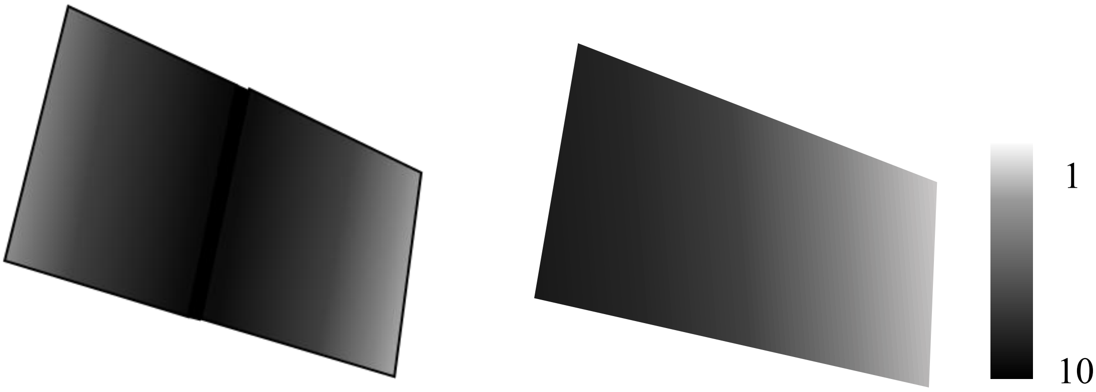


Figure 12. Fertility value map

Road Access: Road is a line feature as it can be accessed directly by columns of pixels, which aggregately equal to the width of the road and connected. For remaining pixels or points, additional pathways parallel to State highway on the edge of the land on South side should be developed. Therefore, road is modelled as a linear feature of 2 m width having maximum value at nearest pixels. However, its value decreases linearly with distance on both East and West sides modelled as linear function (value of 10 at the strip and all rest of the area has linearly decreasing value between 10 and 1).

Marketplace distance: Value for marketplace depends upon the direct distance between a column of pixels to the marketplace. Thus, value of marketplace is maximum at a points or column of pixels nearest to marketplace and decreases linearly with distance.

Figures 13a and 13b, respectively, show the value maps for access to road and marketplace. For marketplace, maximum value of 10 is assigned to pixels that are nearer to the marketplace and minimum value of 1 in opposite direction. Value map for road access has maximum value of 10 at road and minimum of 1 at farthest points in East and West sides of the road.

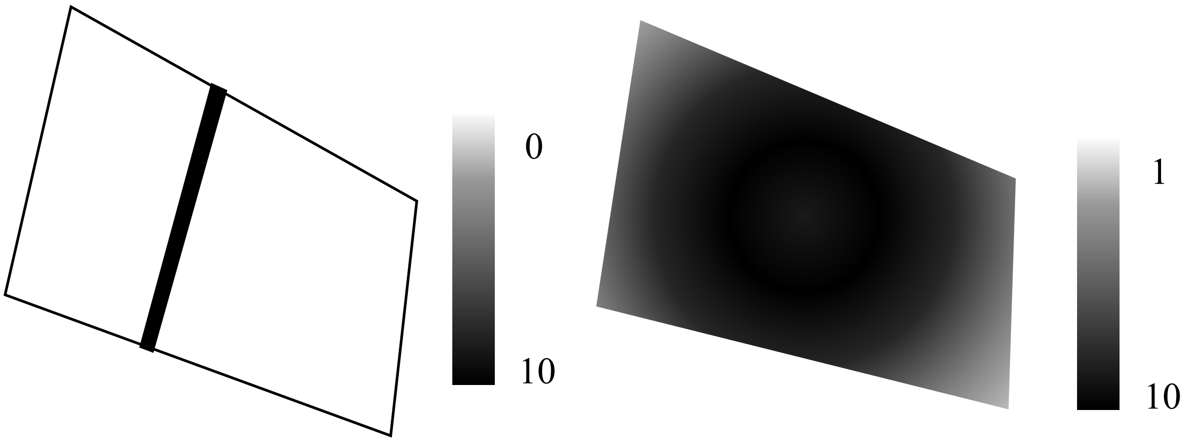


a) Road access value map a) Marketplace distance value map

Figure 13. Value maps for road access and marketplace distance

Shed (fixed property): A small shed is located on the land that is used for many purposes like storage of farming equipment, harvested crop or husk, cattle etc. It can only be accessed if it is contained by a parcel. It is modelled by a step function and hence, the stretch of the land containing the shed is valued maximum (equal to 10) and remaining areas have 0 value.

Irrigation facility: A bore well in the North West corner of the land is the only source of irrigation. It is modelled as point source and its value decreases linearly with distance away from it in all directions. As a result, South East corner of the land has minimum value of 1. Figures 14(a) and 14(b) depicts the value maps for shed and irrigation facility, respectively.



a) Fixed property value map a) Irrigation facility value map

Figure 14. Fixed property and irrigation facility value maps

Averaging of all five maps provide the total value map as shown in figure 15 below.

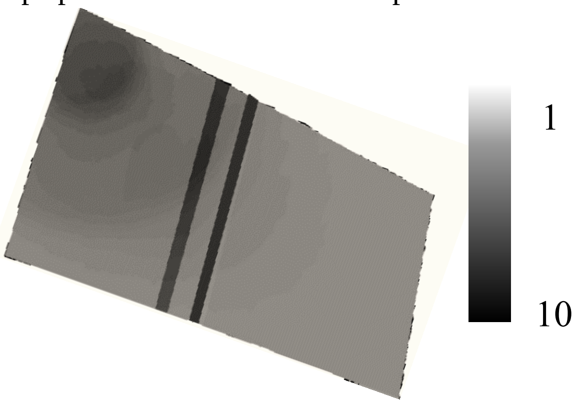


Figure 15. Total value map

The total value of the land is determined by summing all the pixel values of total value map, which is calculated as 11428121 units. Thus, for equal value, each of the four owner should get a total value equal to 2857030 units.

4. RESULTS AND DISCUSSION

The total value map is divided into four equal valued land parcels. Column of pixels are assigned perpendicular to the road direction in sequence from one side of the land. Figure 16 below shows four new parcels allocated by the algorithm. The dimensions on the map are derived from the partitioned total value map, and then transferred to the map of study area in ArcGIS. The final partitions obtained are shown as P1, P2, P3, and P4 in figure 17.

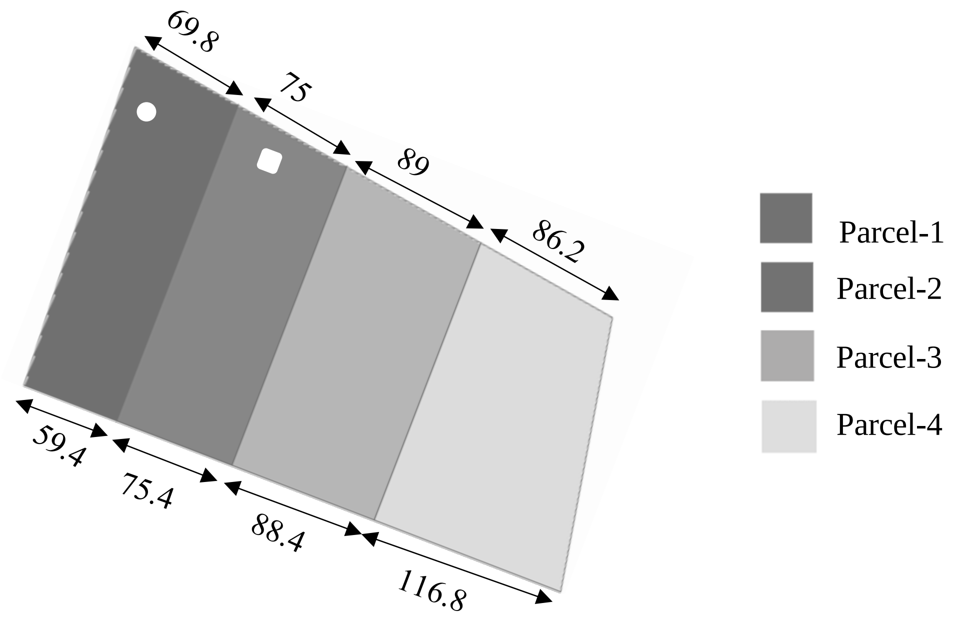


Figure 16. The partitioned land parcels (all dimensions are in meters). Well and shed are shown by circle and rectangle symbols, respectively (not to scale).

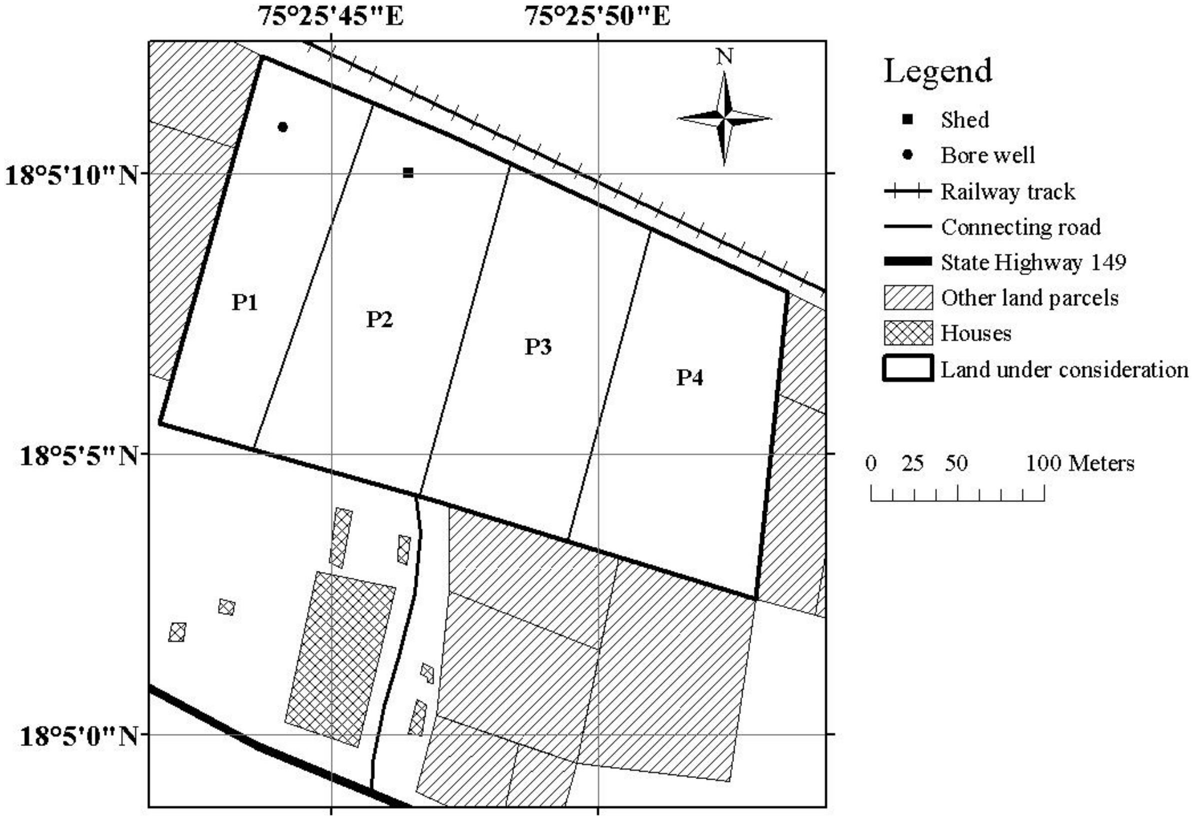


Figure 17. Partitioning performed by the proposed algorithm

The values assigned to the parcels (P1 to P4) from left to right are 2862618, 2857329, 2862291 and 2845883 units, respectively. The partitioning allocates the irrigation facility to the first parcel (P1) from left. The shed is allocated to the second parcel (P2), and the road to the third parcel (P3). The parcels away from the facilities are compensated by more areas having equivalent value. The first parcel has the advantages of irrigation facility, being close to marketplace, and better than average fertility. Hence, it receives least amount of area of land with the same value. The second parcel receives the advantage of moderate fertility and the shed access, along with less distance to irrigation facility compared to third and fourth parcels (P3 and P4). Therefore, the area of second parcel is more than that of first parcel and less than third and fourth parcels. The third parcel although gets access to road has less fertility compared to second parcel and is at larger distance from irrigation facility. Hence, it receives slightly larger area as compared to the first and second parcels. The fourth parcel receives maximum area with minimum facilities. Error for each parcel is expected at the boundaries of the parcels. Amount of error is in order of value contributed by a column of pixels. The error in this case study is found to be less than 1% of reference value (2857030 units) for each parcel.

5. CONCLUSION

finite area and zero value otherwise, whereas a linearly varying function show non-zero values outside the finite area of maximum value.

iv. A parcel will have maximum area if it carries minimum values from all sources, as can be seen for the fourth parcel (P4).

v. The algorithm formulated for partitioning in this study delivers parcels with straight boundaries. It is obvious that the algorithm guarantees successive partitioning, which will be sustainable over generations Also, the algorithm requires minimum human intervention for decision making. On the other hand, it is expected that smaller pixel size on ground will create smoother boundaries at the expense of higher computational time.

The above discussion indicates that the approach developed is a step towards automated solution for land partitioning problems. Authors envision to extend the approach to consider partitioning of lands located adjacent to public properties like roads, railway lines, electricity towers etc., which impose stringent government regulations for the land use. It would also be interesting to perform study with different weights to factors considered. Further, challenges imposed by irregular shapes of land and parcels will should also be addressed in future.

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BIBLIOGRAPHICAL NOTES

Ajay Dashora is a faculty member at Indian Institute of Technology Guwahati. He completed his MTech and PhD in Geoinformatics from IIT Kanpur in 2005 and 2013, respectively. His research interest includes physical modelling, algorithm development, synthetic simulation, and develop low cost methods for various problems like land partitioning and land consolidation.

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Bharat Lohani received the Ph.D. degree from the University of Reading, Reading, U.K., in LiDAR technology and environmental sciences, in 1999. He is currently a Professor with the Indian Institute of Technology Kanpur, India, where he has been since 2002. He has interest in teaching and research in the domain of laser scanning-data capture, processing and application development, which are used for land surveying.

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