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Optimized Locations for Biomass Power Plants using Ant Lion Optimizer in District Bathinda, Punjab, India

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ABSTRACT: District Bathinda of Punjab is well known for its crop production. According to Punjab statics, every year nearly 66.79 % of agriculture waste is burned in open fields which causes global warming and health hazard issues. Agriculture waste known as biomass can be used as a solution to generate power. It needs effective planning, in order to use biomass as a power generation solution. Prediction of optimized biomass based power plants is a challenge for researches from many years. It becomes more challenging when we consider NDVI band while optimizing biomass based power plants. One of the main contributions of this proposed study is that it considers vegetation area which is referred as NDVI in the calculations of optimized biomass power plant locations. Proposed work uses Geographic Information System (GIS)-Model based Normalized Difference Vegetation Index (NDVI) prediction which further fed to optimization model for prediction of best suitable locations for biomass facilities. Optimized locations reduce the extra cost of transporting biomass residual to the decided power plants. This study involves to find the optimized locations for biomass power plants using GIS-NDVI in various blocks of District Bathinda, which enhances the accuracy of optimization model. In this study, the biomass produced by the crops having lesser value of CRR (crop to residual ratio) has been neglected.

Keywords: Agricultural waste, Ant Lion optimization, Biomass power plant, Crop to residual ratio (CRR), Crop residual, Net Surplus, optimal locations, Power potential.

I. INTRODUCTION

India is one of the highest producers of wheat and rice that also states that it has highest crop residual to manage. District Bathinda of Punjab is well known for its crop production. According to Punjab statics, every year nearly 66.79 percent (Punjab Statics 2012-14) of agriculture waste is burned in open fields which causes global warming and health hazard issues [13]. Management should be done in an efficient way. Many researchers have done work in this field. In study Chauhan (2011) [6] authors have predicted the power generation with the help of crop residual of the whole state of Punjab, India. According to this study, power generated by basic surplus residues is 1.510 GW and power generated through net surplus residues is 1.464 GW. Traditional methods for generating electricity is always challenging so they proposed a better approach to overcome those challenges. They have shown biomass advantages and used various decision-making techniques together to optimize the geographical location of biomass. They used fuzzy logic with weighted linear combination. This study was based on the data of Guilan Province, Iran. This study has shown better results than the traditional works [7]. A system consisting biomass power generation plant, absorbers and thermal energy storage was proposed [8]. The main focus of this study was to build an economical model and they were very much successful in achieving a better economic Figure even for residential areas, [24] have taken various basic factors in account to make an optimized model for the biomass power plants. These factors are collection, processing cost and transportation of biomass. Their main focus was to develop an economically better model [10] have used GIS evaluation with Weighted Linear Combination and various decision-making networks like Fuzzy logic to optimize the location of biomass power plant. An integrated model for location optimization of biomass plants has been developed [11]. They concluded that sensitivity analysis is a better approach for optimization. This study also highlighted that locations near the forests are better considering low transportation cost. As per study based at Vietnam, a 3-staged system for optimizing site of biomass has been developed [23]. In first stage fuzzy multicriteria decision making technique was implemented for location optimization. In second stage weights were identified using fuzzy analytic hierarchy process and the third stage consist Technique for Order Preference by Similarity to an Ideal Solution. For evaluation of vegetation covered area NVDI is considered as the most reliable index. Salajanu & Jacobs (2005) used satellite data to calculate the biomass obtained through national inventory [19]. This study used decision making techniques and NDVI on satellite data. The results were compared to the forest inventory data. The results obtained have shown difference less than 2%. In one more study, the authors have focused only on the paddy crops. The study was more like theoretical in nature which states that paddy crops are very nutritious for the fields so instead of burning them author referred to mix the residual with the soil to form an organic manure. But this is very much time consuming [12]. One of the advantage of this study is that both organic and inorganic waste was taken into account. Thomas *et al*., (2013) [24] analyzation of relationship between spatial supply and demand supply has been done in respect of biomass energy. The study was based on England with the help of GIS mapping techniques. They provided a generalized approach considering whole country at once. Factors like transportation and optimal locations are also taken in account. Crop residue is taken as the input for the biomass power plant. This residue totally depends on the quality and quantity of crops yielded per year [22]. Crop yield is very much dependent on the soil fertility so many researchers proposed a model in which they took soil qualities as major parameters to calculate the crop residual [14,15, 17, 18]. This approach can provide precise results but field visits are difficult to implement as the focused area is very large. Also, this could be very much expensive and time consuming. As mentioned above that field visits were a tedious task to implement, so studies used previous data of soil quality to predict the change in soil quality for calculation of crop residual using different software platforms [1, 3, 18, 20]. Obtained results were not significant. All these aforementioned researches have only considered uniform spatial distribution of biomass generation for prediction of optimized location. It means that the biomass produced at each geo-location within a region is assumed to be equally distributed. To avoid this problem, in this study, the prediction of vegetation index using NDVI channel has been performed for geolocations before optimization of biomass power plants. Evaluation result shows the variation in biomass facilities' location with proposed work.

II. NDVI CALCULATIONS

This section involves the identification of geographical area of study and biomass calculations.

A. Geographical Area of Study

Proposed study considered the area encapsulated by geo coordinates 30°36'25"N 74°36'59"E, 30°36'25"N 75°26'35"E, 29°44'34"N 75°26'35"E and 29°44'34"N 74°36'59"E. The altitude of this focused area is 210 m above the sea level. The focused district has seven blocks namely Sangat, Rampura Phool, Maur, Phool, Nathana, Bathinda, and Talwandi Sabo. Fig. 1 shows the geographical representation of the study area.

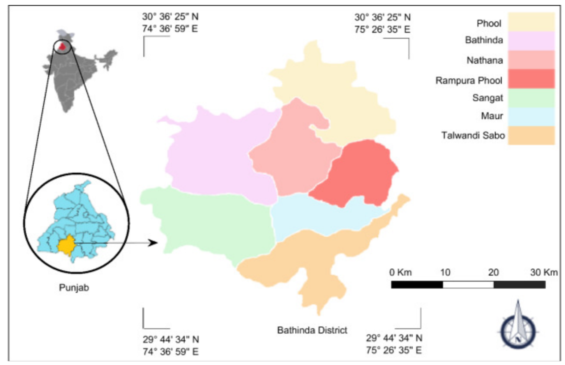
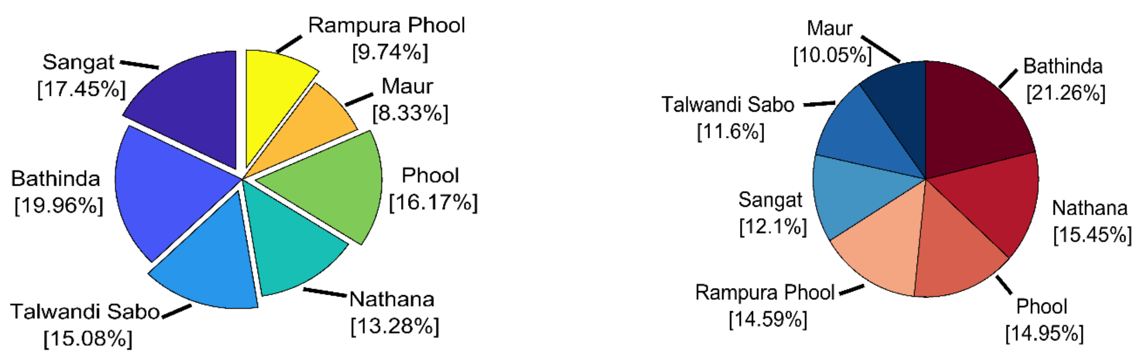


Fig. 1. Geographical area under study in district Bathinda.

Fig. 2 (a) is the Pie chart representing geographical area covered by various blocks of district Bathinda. Sangat holds maximum area of all which is 17.45% of total area of district Bathinda. There are three major types of soil present in this district which are sandy soil, loamy soil and sandy loamy soil. The temperature of this area ranges from 5° to 47° Celsius and the rainfall experienced throughout the year is 488-960 mm [6]. These climatic conditions are favorable for crop production throughout the year. Major Rabi crops are wheat and barley whereas major Kharif crops are cotton and paddy in Bathinda district [16]. Fig. 2 (b) is the pie chart representing agricultural area of the various blocks of district Bathinda (Punjab). It has been noted that block Bathinda have the maximum agricultural area with 21.26% of the total agricultural area.



(a) Percentage-wise Geographical Area

(b) Percentage-wise Agricultural Area

Fig. 2. Geographical and Agricultural Area Percentile.

B. Estimation of NDVI with GIS Model

Normalized difference vegetation index (NDVI) has been used to calculate the density of vegetation in the region. Landsat Collection has 11 bands but none of them gives direct calculation of vegetation area unless we use NDVI calculations ("Long Term Satellite Data Application FOR SVI (i , j , t) = [NDVIcur (i , j , t)– NDVIav (i , j , t)]/ σ (i , j , t)," (2003) [13].

$$\mathrm{NDVI} = \frac{\mathrm{RED} - \mathrm{NIR}}{\mathrm{RED} + \mathrm{NIR}} \quad (1)$$

RED denotes reflectance of the visible band whereas NIR (near-infrared) shows the reflectance. Eqn. (1) shows NDVI prediction using 0.64 – 0.67 μm and 0.85 – 0.88 μm bands. Proposed work uses data from USGS (“Earth Explorer - Home,” n.d.) [9] for the above given coordinates for calculating NDVI of district Bathinda.

Fig. 3 shows the satellite view of the study area, different Landsat bands including calculated NDVI [2]. For evaluation of vegetation covered area NVDI is considered as the most reliable index. Although there are many methods for the assessment of change in pasture vegetation over a long period of time.

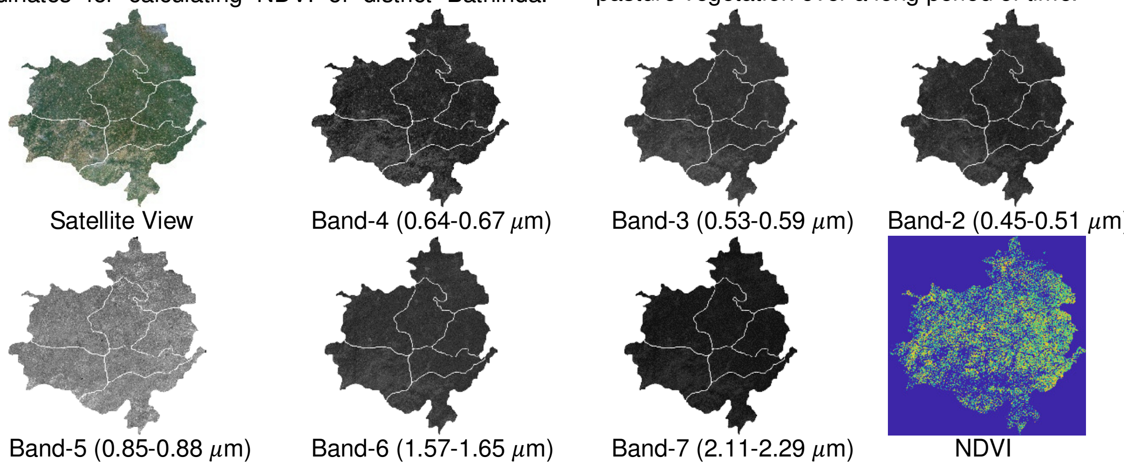


Fig. 3. Satellite View, Landsat Bands, NDVI.

III. METHODOLOGY

A. Prediction of Biomass Potential

District Bathinda alone produced total of 2.858 Mty^{-1} crop residual from major crops. With the use of Eqn. (2), calculations of crop residuals for all blocks have been performed individually as shown in Table 1. The crop residual is of three types mainly; straw, husk and stalk. As district Bathinda is a well-known producer for wheat and paddy, this contributes to 96 % of the crop residual among all other crops and Cotton 2%, Mustard 0.2%, Barley 0.1% contributes in crop residual in the district. Table 2 shows crop production for all blocks along with the crop residuals. Block Bathinda produced maximum crop residual of 607.80 kty^{-1}, whereas other blocks production is as follows: Nathana 441.69 kty^{-1}, Phool 427.40 kty^{-1}, Rampura Phool 417.11 kty^{-1}, Sangat 345.92 kty^{-1}, Talwandi Sabo 331.61 kty^{-1} and Maur 287.31 kty^{-1}. Fig. 4 depicts the graphical representation of various crop residues.

Produced Crop residual = CRRi – [crop area covered (Ai) × crop yield (Yi)] [5, 6] (2)

Table 1: CRR values of crop residues.

Season	Crop Residue	Residue Type	CRR Value
Kharif	Paddy	Straw	1.20
		Husk	0.16
	Cotton	Stalk	1.00
Rabi	Wheat	Straw	1.15
		Husk	0.16
	Barley	Stalk	1.20
	Mustard	Stalk	1.72
Source: [6]			

Table 2 shows crop residual production using crop production taken from Punjab Statics (Statistical Abstract of Punjab-2018). Table 3 shows volume of straw, husk and stalk for major crops of district Bathinda. This clearly shows that straw contributes major role in total crop residual due to higher production and higher CRR values. Straw contributes 85.05 % of the total crop residual type which is 243.16 kty^{-1}, husk is of 11.65% that is 332.93 kty^{-1} and stalk is 03.30% that is 94.20 kty^{-1}.

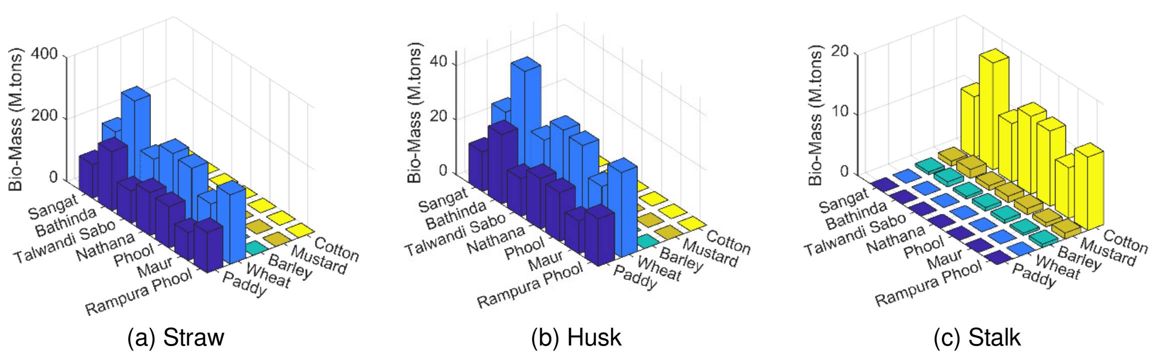


Fig. 4. Graphical Representation of various Crop Residual.

Table 2: Crop Production and Crop Residue Production.

	Crop Production (kty^{-1})							Total Crop Residual Generation (kty^{-1})					
Blocks	**Wheat**	**Paddy**	**Cotton**	**Mustard**	**Barley**	**Total**		**Wheat**	**Paddy**	**Cotton**	**Mustard**	**Barley**	**Total**
Sangat	161.53	90.38	10.10	0.48	0.38	**262.87**		211.61	122.92	10.10	0.83	0.46	**345.92**
Bathinda	283.82	158.81	17.75	0.85	0.68	**461.91**		371.80	215.98	17.75	1.46	0.81	**607.80**
Talwandi Sabo	154.86	86.65	09.68	0.46	0.37	**252.02**		202.86	117.84	09.68	0.79	0.44	**331.61**
Maur	134.16	75.07	08.39	0.40	0.32	**218.34**		175.75	102.10	08.39	0.69	0.38	**287.31**
Nathana	206.25	115.41	12.90	0.61	0.49	**335.66**		270.19	156.95	12.90	1.06	0.59	**441.69**
Phool	199.58	111.67	12.48	0.59	0.47	**324.79**		261.45	151.88	12.48	1.02	0.57	**427.40**
Rampura Phool	194.58	108.98	12.18	0.58	0.46	**316.78**		255.15	148.22	12.18	1.00	0.56	**417.11**
Total	**1335.0**	**747.00**	**83.50**	**04.00**	**03.20**			**1748.90**	**1015.90**	**83.50**	**06.88**	**3.84**	

Source: Punjab statics [16]

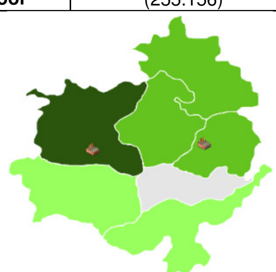
B. Optimal Locations of Biomass Power Plants

Proposed work uses Ant Lion optimization (Mirjalili, 2015) [14] to optimize locations for bio mass power plants. As we have already concluded geo locations of biomass using GIS ("EarthExplorer - Home," n.d.) [9] NDVI model of year 2017-18, next step is to optimize locations of biomass power plants accordingly. Biomass facilities require dependable fitness function to make model prediction more accurate. As it has been seen in Eqn. 3, the summation of distances from biomass production sites to biomass power plants are used, this should be reduced using optimization as much as possible.

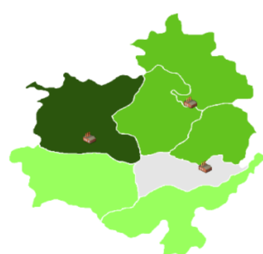
This work considered three possible ways to optimize and categorize the biomass into zones. Every time the optimized locations have divided the study area into various biomass zones. Each zone has one biomass facility and that facility will treat the biomass production of that respective zone. For this study, 1000 iterations have been considered. It results the various locations in form of pixel coordinates in GIS-frame, and it has been changed into geo coordinates using normalization and distance calculations. This work assumes that there will be straight transportation from biomass production site to biomass power plant(s), therefore no collection centers has been taken into account.

Table 3: Crop Residuals Detailing.

Blocks	Wheat (Straw + Husk + Stalk)	Paddy (Straw + Husk + Stalk)	Cotton (Straw + Husk + Stalk)	Mustard (Straw + Husk + Stalk)	Barley (Straw + Husk + Stalk)
Sangat	185.765 + 25.846 + 0 (211.611)	108.464 + 14.461 + 0 (122.925)	0 + 0 + 10.103 (10.103)	0 + 0 + 0.832 (0.832)	0 + 0 + 0.464 (0.464)
Bathinda	326.394 + 45.411 + 0 (371.805)	190.574 + 25.409 + 0 (215.983)	0 + 0 +17.752 (17.752)	0 + 0 + 1.462 (1.462)	0 + 0 + 0.816 (0.816)
Talwandi Sabo	178.089 + 24.777 + 0 (202.866)	103.982 + 13.864 + 0 (117.846)	0 + 0 + 9.686 (9.686)	0 + 0 + 0.798 (0.798)	0 + 0 + 0.445 (0.445)
Maur	154.292 + 21.466 + 0 (175.758)	90.088 + 12.011 + 0 (102.099)	0 + 0 + 8.391 (8.391)	0 + 0 + 0.691 (0.691)	0 + 0 + 0.385 (0.385)
Nathana	237.196 + 33.001 + 0 (270.197)	138.493 + 18.465 + 0 (156.958)	0 + 0 + 12.900 (12.900)	0 + 0 + 1.062 (1.062)	0 + 0 + 0.593 (0.593)
Phool	229.519 + 31.933 + 0 (261.452)	134.011 + 17.868 + 0 (151.879)	0 + 0 + 12.483 (12.483)	0 + 0 + 1.028 (1.028)	0 + 0 + 0.574 (0.574)
Rampura Phool	223.992 + 31.164 + 0 (255.156)	130.784 + 17.437 + 0 (148.221)	0 + 0 + 12.182 (12.182)	0 + 0 + 1.003 (1.003)	0 + 0 + 0.560 (0.560)

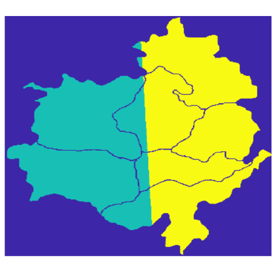


Two Optimal Locations.

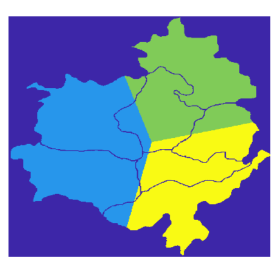


Three Optimal Locations.

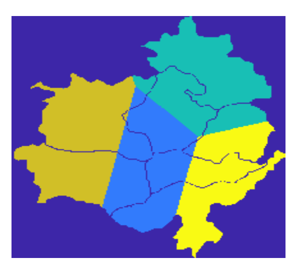
Four Optimal Locations.



Coverage Area with two Locations.



Coverage Area with three Locations.



Coverage Area with four Locations.

Fig. 5. Optimal Locations and Coverage Locations.

One of the main contributions of this work is, considered covered area is not circular. This assumption can lead in false prediction of biomass sites at map boundaries

$$F(x) = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} \min\{\sqrt{(A_{x,j} - C_{x,i}) - (A_{y,j} - C_{y,i})}\}}{m} \quad (3)$$

where m is the Biomass Geographical Locations and n are the number of optimal power plants. $(A_{x,j}, A_{y,j})$ is coordinates of j^{th} power plant. $(C_{x,i}, C_{y,i})$ are coordinates of i^{th} biomass location.

Algorithm: Ant lion Optimization for Minimizing F(x)

1. *Population initialization of Ants and Antlions*
2. *Calculating fitness values of Ants and Antlions*
3. ***while** halting condition not satisfy **do***
4. ***for** i = 1 to i =β **do***
5. *Selection of Ant-Lion with Roulette Wheel*
6. *Update c_i and d_i equations given below*
7. *Random Walk Pattern for Ant-Lions*
8. *updation of fitness values*
9. *Calculation for best fitness values among Ants and Antlions*
10. *Replacing week Antlions with t Antlions*
11. ***end for***
12. ***end while***

where β= Number of Antlions. Ci=c_i/I, di=d_i/I

C. Biomass Power Plant Calculations

Total calculated surplus biomass for district Bathinda in batch year 2017-2018 is 2512 Mty^{-1}; this total surplus biomass is distributed to optimal locations for power generation. It is observed that if the study area of district Bathinda is optimized for the two biomass power plants then surplus biomass for them will be 426 kty^{-1} and 506 kty^{-1} respectively whereas power generated by the plants is 56.03 MW and 66.53 MW respectively.

On the other hand, if we optimize for four power plants then generated power will be 34.92 MW, 33.40 MW, 24.65 MW and 29.60 MW with net surplus biomass of 265 kty^{-1}, 254 kty^{-1}, 187 kty^{-1} and 225 kty^{-1} respectively. The calculations of power generation with crop residual, prediction of calorific value and conversion factor has been done using a research work of IISc (Indian Institute of Science) Bangalore. Table 4 shows net surplus with calculated power generations along with geo coordinates of the biomass facilities.

Power potential (MWe) = available biomass (kty^{-1}) × energy content of biomass (MJkg^{-1}) × power cycle efficiency (4)

(Gupta *et al.*, 2004), ("MNRE. Ministry of New and Renewable Energy Resources - Google Search," n.d.) [6].

Table 4: Power Plant Potential and its Locations.

No. of Optimal Locations	Net Surplus (kty^{-1})	Optimal Geo-Coordinates	Nearest City/ Village (Block)	Power Generation Potential (MWy^{-1})
Two locations	Ist Plant 426	**Lat:** 74°52'50"E **Long:** 30°10'20"N	Multania (Bathinda)	56.03
	IInd Plant 506	**Lat:** 75°13'50"E **Long:** 30°11'40"N	Bhunder (Rampura Phool)	66.53
Three locations	Ist Plant 381	**Lat:** 74°52'30"E **Long:** 30°10'30"N	Multania (Bathinda)	50.16
	IInd Plant 282	**Lat:** 75°11'40"E **Long:** 30°17'50"N	Mehraj (Phool)	37.10
	IIIrd Plant 268	**Lat:** 75°14'40"E **Long:** 30°04'40"N	Maur (Maur)	35.30
Four locations	Ist Plant 265	**Lat:** 74°50'00"E **Long:** 30°11'00"N	Teona (Bathinda)	34.92
	IInd Plant 254	**Lat:** 75°12'50"E **Long:** 30°18'30"N	Phul (Phul)	33.40
	IIIrd Plant 187	**Lat:** 75°16'00"E **Long:** 30°04'40"N	Ghuman Kalan (Maur)	24.65
	IVth Plant 225	**Lat:** 75°03'10"E **Long:** 30°07'50"N	Kot Shamir (Nathana)	29.60

IV. RESULTS AND DISCUSSIONS

Proposed model implemented on computer with configuration of 8gb RAM, 1050i Nvidia GPU and i5 processor. It took 940 seconds to predict four optimized locations of biomass power plant considering 1000 running iterations with 100 Antlions.

Table 4 shows variation of power plants potential and its distribution areas with the change in number of optimized locations from 2 to 4. Result shows that geolocation of power plants mainly falls near the area having dense biomass potential as compare to study conducted with Punjab statics 2001-02 [21].

Power generation for four plants is 34.92, 33.40, 24.65 and 29.60 MW, difference in power potential varies with 1.52 to 10.27 MW which shows the balancing of biomass processed by biomass facility over the year. Fig. 5 shows heat map of geographical areas covered by each biomass facility and it is observed that area under each facility is nearly equal.

Results also reflect that electric power generation potential is maximum for power plant near Bathinda block which is 34.924 MW and minimum for power plant near Maur block having 24.65 MW for four optimized locations of biomass power plants.

V. CONCLUSION

This study shows that total generation of power using biomass in district Bathinda is 122.56 MW, which is a significant electric power to serve the consumers. It is observed that paddy and wheat are the major crops because they contribute 96% of total biomass produced in district Bathinda. Proposed research shows that generation of power using agriculture waste is a better option in spite of burning it in open fields. This will not only reduce air pollution but will help to enhance the income of farmers. It will also provide the energy security for future generations.

VI. FUTURE SCOPE

Proposed study assumes that collection centers are just near to the biomass power plants facilities. In future work optimization of collection centers can be considered to reduce transportation cost. This study uses Euclidean distances for fitness function equation, which can be taken with the help of road map for further study.

Conflict of Interest. There is no conflict of interest.

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