

Article GIS-Based Cluster and Suitability Analysis of Crop Residues: A Case Study in Yangon Region, Myanmar

Tin Min Htoo¹, Helmut Yabar^{2,*} and Takeshi Mizunoya²

- Degree Programs in Life and Earth Sciences, Graduate School of Science and Technology, Doctoral Program in Environmental Studies, University of Tsukuba, Tsukuba 305-8572, Japan
- ² Graduate School of Science and Technology, University of Tsukuba, 1-1-1 Tennodai, Tsukuba 305-8577, Japan
 - Correspondence: yabar.mostacero.h.ke@u.tsukuba.ac.jp

Abstract: In the study of biomass assessment, geospatial modeling-based analysis becomes crucial for the sustainable management of agriculture. Currently, there is no integrated sustainability assessment of the geographic information system (GIS) cluster or suitability analysis for the feedstock of crop residues. In order to fill this research gap and support the strategy of bioenergy formulation with the circular economy concept in agriculture residues in Myanmar, this study aims to assess the energy generation potential and site locations of treatment facilities for crop residue, utilizing the integrated assessment of GIS cluster and suitability modeling. The cluster analysis identifies the rice straw as the highest feedstock of crop residues and township-based high/low clusters. In addition, the electricity generation potential is estimated at 279.14 MW for different clusters of rice straw. Moreover, the suitability analysis in the study uses the conceptual model of variables for constraints and factors with the analytical hierarchy process (AHP) technique to evaluate the weights. The suitability analysis found high suitability areas of 14,603 hectares for treatment facilities within the high/low cluster of feedstock for rice straw. The multicriteria and GIS integrated assessment model adopted in this research can support the decision-makers in developing spatial-based strategic planning for bioenergy promotion which will support sustainable farming practices in Myanmar. Additionally, the proposed model is adaptable in study areas with similar feedstock.

Keywords: crop residue; bioenergy; geographic information system (GIS); cluster analysis; suitability analysis; analytical hierarchy process (AHP); energy generation

1. Introduction

Myanmar's agriculture-based economy has resulted in an abundance of biomass resources. Every year, Myanmar produces more than 20 million tons of paddy [1]. In addition, future population growth may increase the need for food production, quickly increasing the possibility of crop residue creation. Fuelwood, wood by-products, rice husks, straw, coconut, sugarcane, palm oil, cassava, maize, manure from livestock, and poultry sector by-products are the primary biomass sources in Myanmar [2]. The traditional practices of utilizing biomass in Myanmar are cooking, heating, animal feeding, dumping, and open burning [1]. However, current management practices frequently negatively affect the environment, society, and economy. According to the studies, Asian countries accounted for one-third of global biomass greenhouse gas emissions due to the open burning of agricultural wastes [3]. Correspondingly, the Food and Agriculture Organization of the United Nations explained that Myanmar has a carbon dioxide equivalent [CO₂ eq) emission value of 2124.5 for crop residue [4].

According to the waste management strategy in Myanmar, one of the principles is to promote the most efficient use of resources, including resource recovery and waste avoidance. Myanmar's climate change master plan also aims to develop practices for mainstreaming GHG emission reduction into agriculture [5]. Energy utilization of residual



Citation: Min Htoo, T.; Yabar, H.; Mizunoya, T. GIS-Based Cluster and Suitability Analysis of Crop Residues: A Case Study in Yangon Region, Myanmar. *Appl. Sci.* **2022**, *12*, 11822. https://doi.org/10.3390/app122211822

Academic Editor: Anselme Muzirafuti

Received: 27 October 2022 Accepted: 16 November 2022 Published: 21 November 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). biomass becomes an optimal solution for sustainable waste management to develop the country's energy security as renewable energy [6]. Agricultural residues, such as rice husk and rice straw, have been used worldwide to produce renewable energy [7]. Therefore, bioenergy conversion of crop residues has become one of the effective strategies for the sustainable management of crop residues in Myanmar.

Scientific studies have demonstrated that it is possible to generate a wide variety of bioenergy and other applications from biomass residues and waste from raw goods slanted, processed, and consumed [8]. The technologies for energy conversion of biomass residue are mainly classified under thermochemical or biological methods [9]. There are some factors that influence the choice of a conversion technology to be applied to biomass in terms of quantity of the biomass feedstock, availability, choice of end-products, process economics, and environmental issues [10]. The combustion method is widely used because it is easy to implement into thermal or electrical mechanical energy.

The energy content of crop residues depends on the available feedstock of crop residue and its heating value [11]. One popular method for estimating biomass feedstock from crop residues uses the residue-to-product ratio l [12,13]. A. Chauhan et al. calculated the crop residues using crop yield and total production of crops [14]. The entire crop of straws was estimated using the economic crop yield and the straw production coefficient [15]. Jiang, Y et al. calculated the energy potential of crop residue using the official statistic of production data, residue-to-crop ratio, the lower heating value, and conversion factors [16]. Cuong et al. estimated the electricity generation of biomass using data from feedstock of crop residues, latent heat value, moisture content, and energy efficiency [17].

The spatial distribution of energy potential and feedstock crop residue can be identified using Geographic Information System (GIS). The goal of cluster analysis is to determine if a dataset comprises a single group or contains subgroups to select how many clusters are in the data [18,19]. M. Svazas et al. considered that reducing communication and transportation expenses is the primary justification for clustering because geographic proximity enables businesses to access a big pool of suppliers [12]. For GIS cluster mapping, V. Prasannakumar et al. used the ArcGIS tools of Spatial Autocorrelation Moran's I method, and Getis-Ord GI* function and density estimation using Kernel density tool to find the road accident hotspots [20]. K. M. Dao et al. applied ArcGIS in terms of the "Calculate Distance Band from Neighbor Count", "Incremental Spatial Autocorrelations", and the "Getis-Ord GI*" function to make the clusters of pig farms [21]. F. Venier and H. Yabar grouped cattle farms according to their sizes in terms of large, medium, and minor scales using GIS [22].

Globally, to achieve the goal of sustainable renewable energy development, most countries worldwide have worked hard at a regional and global level by constructing biomass treatment facilities using spatial analysis [23]. Therefore, geospatial consideration and location modeling are required for a suitable location of treatment facilities' site selection and analysis. Another strand looks at land suitability analysis and site selection for urban and rural agriculture using a variety of methodologies, such as multicriteria decision-making (MCDM) [24].

MCDM approaches are utilized in site selection applications to determine the weights of defined main/sub-criteria [25]. R. Rios and S. Duarte considered the thirty-three constraints and seven criteria factors for GIS suitability analysis [26]. E. C. Chukwuma et al. studied the suitability map for biogas power plants using the constraints of rural and urban areas, park and recreational areas, water bodies, wetlands, roads, transmission lines, and slopes [23]. L. Jayarathna et al. considered the criteria factor in terms of vegetation cover, crop cover, slope, road proximity, transmission line proximity, workforce potential, energy demand potential, population exposure, and viewshed to locate the biomass energy plant [27]. Nantasaksiri, K et al. use the analytical hierarchy process (AHP) of multicriteria decision-making to evaluate the weight of the factors [28].

Currently, there is no integrated assessment of the GIS cluster and site suitability analysis for biomass energy potential. Moreover, to support the strategy of bioenergy formulation with the circular economy concept for agriculture residues in Myanmar, this study aims to assess the energy generation potential of crop residue in terms of the township based spatial high/low clusters and to find suitable sites for treatment facilities for energy generation.

2. Materials and Method

2.1. Study Area

The study area comprises 43 townships in the Yangon Region, which is in the delta area regarding the ecological environment. The selected area is examined to assess the potential locations of treatment facilities based on available clusters of agro residues, refer to Figure 1. In 2019, the Yangon region had a population of over eight million [29] and covered an area of 10,171 square kilometers [30]. It is one of the highest-production areas of rice in Myanmar [31]. Additionally, the major crops in the region are paddy, green gram, groundnut, sunflower, sesame, and sugarcane [32]. Regarding meat from livestock production, cattle, buffalo, pigs, chickens, ducks, and quails are primary sources of meat production [33].



Figure 1. Study Area of Yangon Region, Myanmar.

2.2. Research Flow and Data Collection

This study used ArcGIS Desktop 10.8.1 (Product Version: 10.8.1.14362), developed by Environmental Systems Research Institute (Esri), a company based in California, United States, to perform a GIS cluster and suitability analysis, as shown in Figure 2.

This study has two categories of data: nonspatial and spatial. The nonspatial data regarding the production number of crop output quantity, electricity access, and water access are collected from Myanmar Information Management Unit [33,34]. The spatial data in land use and land cover maps, digital elevation model (DEM), road, protected areas, and administrative data are gathered from open satellite images of open data sources from the United States Geological Survey(USGS), Environmental Systems Research Institute (Esri) 2020 landcover and Geofabrik website and Myanmar Information Management Unit website, Table A1, Appendix A.



Figure 2. Research Framework.

2.3. Cluster Analysis

Cluster analysis is divided into three components, as follows:

- a. Calculating feedstock of crop residue and selecting of targeting biomass waste type
- b. Township-based cluster analysis of feedstock using ArcGIS
- c. Estimating the electricity generation potential of each cluster

2.3.1. Calculation of Crop Residue

Equation (1) computes the feedstock for the crop residue potential. The RPR values of different crops are shown in Table A2; Appendix A. Grain production data are collected from township profiles from the Myanmar Information Management Unit. The data are processed to connect the attribute table of the vector file of the townships in the study region in the ArcGIS 10.8.1 environment after calculating the biomass waste generation potential from crop residue, as indicated in Equations (1) below:

$$\sum_{i=1}^{n} Gi * RPRi \tag{1}$$

where,

Gi = Grain production

RPRi = residue to crop ratio

Thus, waste generation potential is equal to total grain production given by (*Gi*) times residue to crop ratio denoted by (*RPRi*).

2.3.2. Township-Based GIS Cluster Analysis of the Feedstock of the Crop Residue

After calculating the crop residues in the 43 townships, the selected highest potential of crop residues generation data is prepared in ArcGIS to make the township-based cluster analysis with four steps. In step one, the Spatial Autocorrelation (Global Moran's I) tool simultaneously measures spatial autocorrelation based on selected crop residue generation amounts and township-based locations. It evaluates whether the pattern expressed is clustered, dispersed, or random using Moran's I Index value of both the z-score and *p*-value. The z-score and *p*-value indicate statistical significance. Step two is to determine the average distance of neighbor townships using the tool Calculate Distance Band from Neighbor Count. In step three, the tool of Incremental Spatial Autocorrelations creates a line graph and finds the distances where township-based spatial clustering patterns

occurred with corresponding statistically significant peak z-scores. These peak distances are used as a radius parameter to ensure step four of Cluster and Outlier Analysis (Anselin Local Moran I). It distinguishes between a statistically significant township-based cluster of high values (High-High Cluster), clusters of low values (Low-Low Cluster), outliers in which a high value is surrounded primarily by low values (High-Low Cluster), and outliers in which a low value is surrounded primarily by high values (Low-High Cluster).

2.3.3. Estimating the Electricity Generation Potential of Each Cluster

The electricity generation potential for the township based on high/low clusters was estimated using Table 1.

Table 1. Electricit	y Potential C	alculation Method	d [17].
---------------------	---------------	-------------------	---------

$Ep(MW) = \frac{Rice \ straw \ generation*(1-LRS)*(1-MC)*LHV*\mu}{3.6*OPH}$							
EP = Electricity potential							
LRS = Loss of rice straw during handling and storage (%) = 10							
MC = Moisture content assumed on a dry basis (%) = 12							
<i>LHV</i> = Low heating value of residue (MJ per kg) = 14							
μ = Overall efficiency of the plant (%) = 25							
<i>OPH</i> = Operation hours = 8000							

2.4. Suitability Analysis

In this study, the suitability analysis model Equation (2) is for the locations of treatment facilities for electricity generation of the township-based high/low clusters. The treatment facilities were modeled to reduce the environmental, economic, and social negative impacts on the whole Yangon region. Suitability analysis for GIS-MCDM encompassed two paradigms with the conceptual model where constraints variables and factors variables [35]. In addition, the evaluation of weights for factor variables was analyzed using the multicriteria decision-making method in the analytical hierarchy process (AHP).

$$S = \sum_{i=1}^{n} f_i w_i * \prod_{j=1}^{n} c_j$$
(2)

S =suitability

 f_i = factors variables

 w_i = weight of factors variables

 c_i = constraints variables

i = different restrictions for constraints represented by the individual parameters

2.4.1. Constraints Variables

A restriction serves to limit the options under consideration [35]. The literature study investigated the buffer criteria and distance in Table A3, Appendix B, for restrictions. After processing buffer and union in ArcGIS, the criteria are changed to raster. Finally, using ArcGIS raster calculator, all constraint variables are combined as a restriction map of the Yangon Region.

2.4.2. Factor Variables

A weighted linear combination combines factors variables by assigning each a weight and then summing the results to obtain a suitability map [35]. Factors of the criteria and preference distance are shown in Table A4, Appendix B. The evaluation of weights is calculated from the Multicriteria Decision Making Method. Caprioli, C. and Bottero, pointed out that different multicriteria techniques are used to solve site selection problems [36]. These include the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), ÉLimination Et Choix Traduisant la REalité (ELECTRE), techniques for order preference by similarity to ideal solution (TOPSIS), and Analytic Hierarchy Process (AHP). This paper uses a weight evaluation method based on the AHP methodology. First, criteria factors are processed using Euclidean Distance and Reclassification techniques in Spatial Analyst Tools of ArcGIS 10.8.1, and the weighted overlay is processed using the weighted value from the AHP of MCDM analysis to generate the final suitability map.

The analytical hierarchy process (AHP) is a general theory of measurement to derive ratio scales from discrete and continuous paired comparisons [37]. This study applied it in Table A5, Appendix B. First, the consistency of the matrix data is defined and measured by a formula employing the average of the nonprincipled eigenvalues, which is then compared to other values in a numerical scale ranging from 1 to 9. Since the Consistency Ratio (C.R.) is acceptable at less than 0.1, the evaluated weight of each Factor of AHP is overlayed using the tools of weighted overlay in ArcGIS. Then the restriction map and factor map are combined using the Times of Spatial Analyst Tool of ArcGIS tools to find the final suitability map.

3. Results

3.1. Cluster Analysis

3.1.1. Crop Residue Generation

The information on crop residue generation from 43 townships is shown in Figure 3, and further details are highlighted in Table A6, Appendix C. According to the results of the crop residue generation in Figure 3, rice straw generation amounts to 2,900,157.63 tons/year, which has the highest potential compared to the other 18 types of resides. Therefore, rice straw is selected as the targeted crop residue for township-based clusters in ArcGIS 10.8.1.



Figure 3. Crop Residue Generation from 43 Townships.

3.1.2. Township-Based Clusters Analysis of the Feedstock of the Rice Straw

According to step one, "Spatial Autocorrelation (Global Moran's I)", the z-score is 6.56, and the *p*-value is less than 10% Figure 4. The result indicates that the cluster pattern exists in 43 townships. Then, step two of the tool "Calculate Distance Band from Neighbor Count" finds 6948.84 m as the average distance among 43 townships. Then, step three of "Incremental Spatial Autocorrelations" ensure the result in the peak distance of 20,846.51 m as the radius parameter that promotes the township-based cluster Figure 5. Finally, step four distinguishes township-based clusters of high values (High-High Cluster), clusters of low values (Low-Low Cluster), outliers in which a high value is surrounded primarily by low values (Low-High Cluster) Figure 6, Table 2.



Figure 4. The result of Spatial Autocorrelation (Global Moran's I).



Figure 5. The result of Incremental Spatial Autocorrelations.

Table 2.	The Results of	Township-Based	Clusters Analysis	of the Feedstock	of the Rice Straw
----------	----------------	----------------	-------------------	------------------	-------------------

Township Name	Cluster Type	Rice Straw Generation (ton)	Electricity Potential (MW)
Kungyangon	Not Significant	285,000.43	27.43
Thongwa	Not Significant	381,007.22	36.67
Hmawbi	Not Significant	11,308.38	1.09
Hlegu	Not Significant	292,719.14	28.17
Twantay	Not Significant	291,133.19	28.02
Shwepyithar	Not Significant	274.16	0.03
Taikkyi	Not Significant	170,932.38	16.45

Township Name	Township Name Cluster Type		Electricity Potential (MW)	
Kyauktan	Not Significant	262,814.46	25.30	
Htantabin	Not Significant	355,211.87	34.19	
Kawhmu	High-High Cluster	261,696.52	25.19	
Kayan	High-High Cluster	277,279.32	26.69	
Dala	High-Low Cluster	110,021.13	10.59	
Thanlyin	High-Low Cluster	157,252.94	15.14	
Dagon Myothit (East)	Low-Low Cluster	22,458.52	2.16	
Dagon Myothit (Seikkan)	Low-Low Cluster	15,501.94	1.49	
Mingaladon	Low-Low Cluster	1207.23	0.12	
Kyeemyindaing	Low-Low Cluster	3637.47	0.35	
Seikgyikanaungto	Low-Low Cluster	701.33	0.07	





3.1.3. Estimating the Electricity Generation Potential of Each Cluster

According to the electrical potential of the different township-based clusters in Table 2, the total energy potential into the national grid from rice straw within the 43 townships is 279.14 MW. High-High Clusters have 51.88 MW, while High-Low Clusters have 25.73 MW. Low-Low Clusters have 3.84 MW. Although some of the townships do not exit as cluster patterns, Kungyangon, Thongwa, and Hmawbi have the potential of 27.43 MW, 36.67 MW,

Table 2. Cont.

and 28.17 MW, respectively. Applying the electric potential from different clusters, the decision maker can decide on the strategic plan for bioenergy promotion.

3.2. Suitability Map for Yangon Region

All constraint variables are mapped in Figure A1, Appendix B. The restriction areas of all constraint variables are identified in Figure 7. The restricted areas are represented by green and unrestricted, shown in blue in the Yangon Region. The AHP method gives the results of the evaluated weight of each factor variable in Table 3. For all factor variables, maps are reclassified, Figure A2, Appendix B. The result of the overlays of all factor variables as the preferred areas includes low, intermediate, and high suitability, as in Figure 8. After combinations of variables for constraints and factors, the final suitability map results in terms of no suitability, low suitability, intermediate suitability, and high suitability Figure 9. The resulting areas of the suitability map are classified as follows, low suitability (26,222 hectares), intermediate suitability (111,799 hectares), high suitability (14,603 hectares), and the total available land equivalent to 152,624 hectares. The high suitability areas are identified as the final suitable areas for treatment facilities of electricity generation of township-based clusters.



Figure 7. Constraint Variables for Restriction Map.

Table 3.	Evaluated	Weight by	AHP	Method.
----------	-----------	-----------	-----	---------

Method	Crop and Livestock	Residentia	l Industry	Road	Railway	Waterway	Slope	Electricity Access	Water Supply	Earthquake Faults	Flood Zone
Weight	0.14	0.14	0.14	0.14	0.02	0.02	0.14	0.08	0.04	0.05	0.10
λmax	11.45										
Consistency Index (CI)	0.04										
RI	1.51										
CR	0.02										



Figure 8. Factor variables for Weighted Overlay Map.



Figure 9. Final Suitability Map for Treatment Facilities.

3.3. Site Suitability Locations of Treatment Facilities for Township-Based Clusters

In ArcGIS, township-based clusters are processed to make the intersection with the final suitable areas Figure 10. For the High-High Cluster, the intersection finds 11 areas of polygons with a total area of 292 ha. In addition, there are 19 polygons with 642 ha for the High-Low Cluster, 10 with 334 ha for the Low-Low Cluster, and 229 with 12,358 ha for not significant clusters. This result gives the information to decision-makers to select the strategic locations of treatment within the different clusters.



Figure 10. Township-based Clusters and Locations of Treatment Facilities.

4. Discussion

Under Cluster Analysis, the evaluation of crop residue is based on the yearly production rate (secondary data collected from 43 townships in the Yangon Region, Myanmar). Residue to production ratio RPR and crop production are used to calculate the generation of crop residues. In this study, the production value is collected from the data for 2019 of the general administrative office, which is on the Myanmar Information Management Unit website. Moreover, RPR values are gathered from different countries and different pieces of literature. The disadvantage of this method using RPR values is that different crops may have varied RPR values depending on weather variations, crop types, water availability, soil quality, and farming methods [38]. Therefore, estimating the number of residues using an RPR may result in inaccurate estimates. Thus, the more accurate generation calculation should also depend on the more reliable statistical production data and precise testing results RPR might improve.

Another way to calculate the crop residue which uses crop production is based on the cropped area and is frequently used for woody residues from perennial crops [38]. This approach assumes that the amount of crop and residue harvested from a cropping area can vary significantly depending on the management style (traditional or advanced) and crop variety. The remote sensing method using satellite images is also an efficient and cost-effective way to obtain information concerning crop residue and crop condition cover [39].

In GIS cluster analysis, there are four steps in terms of Spatial Auto Correlation Morans I; Calculate Distance Band for Neighbor Count; Incremental Spatial Autocorrelations, and Cluster and Outlier Analysis (Anselin Local Moran I) in this study. However, instead of action four of Cluster and Outlier Analysis (Anselin Local Moran I), Hot Spot Analysis (Getis-Ord Gi*) can also be used to identify the extraordinary and hot spots.

In GIS suitability analysis, the constraint variables and the factor variables are modeled. When determining whether the land has the potential to meet the criteria, there is no set standard for the assessment of conditions and factors or other considerations. The constraints depend not only on the regulations but also on the sustainability consideration. In this study, evaluating the weight of factors is the AHP method. For factors, the different multicriteria decision-making (MCDM) can be used to solve site selection problems of weighting in terms of preference ranking organization method for enrichment evaluation (PROMETHEE), ÉLimination Et Choix Traduisant la REalité (ELECTRE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and others.

GIS cluster and suitability analysis need vector spatial data that can be classified from a satellite image or related department. In this study, land use and land cover data are mainly from the Environmental Systems Research Institute (Esri) 2020 land cover, which has an accuracy of 87 percent. The other data are downloaded from the Myanmar Information Management Unit.

In this study, The GIS cluster analysis can identify the rice straw as the promising feedstock among crop residues. Furthermore, the township-based clusters are helpful for strategic planning and the suitable location of treatment facilities. Therefore, connecting the cluster of biomass waste with viable facilities should be studied in the future.

5. Conclusions

In this study, the rice straw with the most significant potential is 2,900,157.63 tons/year. The total electricity potential from the rice straw of the Yangon region to the national grid is 279.14 MW. The high/high clusters of Kawhmu and Kayan are suitable townships to promote the bioenergy development plan because these townships are surrounded by high feedstock potential for rice straw. The electric potential of rice straw from Kawhmu and Kayan township is 51.88 MW. Moreover, the suitable locations of treatment facilities for different clusters have 269 polygons with a total area of 13,626 ha. For generating scenarios for optimal biomass management system planning in terms of the transportation network, which is a crucial aspect of feedstock management, it is required to apply the results in this study. For recommendation, the future study should focus on allocating the resource clusters and treatment facilities in road networks and household applications. Moreover, life cycle assessment can be used to assess the performance of GHG emission reduction potentials from different scenarios.

Author Contributions: Conceptualization, H.Y.; Methodology, T.M.H., H.Y. and T.M.; Formal analysis, T.M.H.; Investigation, H.Y.; Writing – original draft, T.M.H.; Writing – review & editing, H.Y. and T.M.; Supervision, H.Y. and T.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: This does not apply to the study.

Data Availability Statement: All data are reported in this work.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

 Table A1. Spatial and Non-Spatial Data.

Data	References
Residentials, crops, forests water body	Esri land cover map [40]
Digital Elevation Model (DEM]	USGS/ Earth Explorer/ SRTM/SRTM 1 arc-second Global [41]
Waterbody	USGS/ Earth Explorer/ SRTM/SRTM waterbody data [41]
Yangon townships boundary map	[42]
Road network	[43,44]
River network	[44]
Railway	[45]
Airport	[46]
Industrial zone from township data	Georeferencing in Arc Map 10.8.1 using maps from Township Profiles [35]
Protected and heritage areas	[47]
Flood zone potential	[48]
Earthquake faults	[49]
Yangon Region landuse, Grain production data from township profiles in Yangon Region, Utilities access data	[43,50]
Medium voltage transmission line	[51]
High voltage transmission line	[52]
Power station	Google Earth

 Table A2. Type of Crop Residue and RPR Value.

Crop Residue	Residue-to-Crop Ratio	Reference		
Rice straw	1.757	[53]		
Rice husk	0.267	[53]		
Ground nut straw	2.3	[54]		
Ground nut husk	0.477	[38]		
Sesame trash	2	[55]		
Sunflower trash	[0.7–3.5] used as 1.5	[56]		
Black gram straw	1.7	[57]		
Black gram husk	0.03	[57]		
Green gram straw	1.7	[57]		
Green gram husk	0.03	[57]		
Pigeon bean straw	1.7	[57]		
Pigeon bean husk	0.03	[57]		
Sugarcane top	0.3	[58]		
Sugarcane bagasse	0.299	[56]		
Maize straw	(0.7–2.5) used as 2	[56]		
Maize husk	0.273	[53]		

Appendix B

Table A3. The Criteria of Constraint Variables and Buffer Distance.

Constraint Variables	References							
Constraint variables –	[23]	[59]	[60]	[61]	[62]	[63]	[64]	Study
Airports		Within 8 km				7–12 km		7 km [63]
Environmentally sensitive areas [forest and mangrove]	500 m	1 km				2 km		1 km [59]
Commercial and recreational areas	500 m	500 m						500 m [59]
Roads		300 m						300 m [59]
Power stations		100 m						100 m [59]
Transmission lines [H.V.]	100 m	100 m						100 m [59]
Slope	15	slopes >15%						15% [59]
Residentials	1 km	1 km		>20 km			0–50 m	1 km [59]
Waterbody	200 m	300 m	Lowest >220 m Highest 0–2 km	Lowest 200 m Highest >10 km	500 m	1000 m	500 m	500 m [62]
Culture important places						5 km		5 km [63]
Road	30 m				1 km		500 m	500 m [64]

Table A4. The Criteria of Factors Variables and Preference Distance.

Factor		This Study						
Variables	[59]	[60]	[61]	[62]	[63]	[64]	- This Study	
Crop land							>500 m	
Residentials	Lowest <1000 highest >4000	Lowest 0–100 Highest > 500	Lowest 0–1.5 km Highest >12 km		500–2000 m	Highest >50	>500 m [63]	
Manufacture							>500 m	
Road	Lowest >2000 Highest <200	Lowest 2 km Highest 200	Lowest –300 m Highest >10 km	<1 km	1500 m	1601–2000 m Highest 501–1000	>200 m [60]	
Railway		Lowest > 20,000 Highest 0-2000			100–500 m		>500 m [63]	
Waterway							>500 m	
Slope			Lowest >20 Highest 0–6			Lowest >30 Highest 0–10	>10 [64]	
Electricity access							Priority on the area where firewood is used [65]	
Water supply access							Priority on tube well use [65]	
Earthquake faults			Lowest 0–2 km Highest >20 km				>2 km [61]	
Flood zone							>2 km	

Table A5. Pairwise Comparison Matrix of Factors.											
	Crop and Livestock	Residential	Industry	Road	Railway	Waterway	Slope	Electricity Access	Water Supply	Earthquake Faults	Flood Zone
Crop	1.00	1.00	1.00	1.00	7.00	7.00	1.00	2.00	3.00	3.00	2.00
Residential	1.00	1.00	1.00	1.00	7.00	7.00	1.00	2.00	3.00	3.00	2.00
Industry	1.00	1.00	1.00	1.00	7.00	7.00	1.00	2.00	3.00	3.00	2.00
Road	1.00	1.00	1.00	1.00	7.00	7.00	1.00	2.00	3.00	3.00	2.00
Railway	0.14	0.14	0.14	0.14	1.00	1.00	0.14	0.13	0.20	0.14	0.14
Waterway	0.14	0.14	0.14	0.14	1.00	1.00	0.14	0.20	0.33	0.33	0.20
Slope	1.00	1.00	1.00	1.00	7.00	7.00	1.00	3.00	5.00	3.00	2.00
Electricity Access	0.50	0.50	0.50	0.50	8.00	5.00	0.33	1.00	3.00	2.00	0.33
Water supply	0.33	0.33	0.33	0.33	5.00	3.00	0.20	0.33	1.00	0.50	0.20
Earthquake Faults	0.33	0.33	0.33	0.33	7.00	3.00	0.33	0.50	2.00	1.00	0.33
Flood zone	0.50	0.50	0.50	0.50	7.00	5.00	0.50	3.00	5.00	3.00	1.00
SUM	6.95	6.95	6.95	6.95	64.00	53.00	6.65	16.16	28.53	21.98	12.21



Figure A1. Cont.







Slope



Road

Railways

Earthquake faults



Proximity to Cropland

Å



Waterway



Energy use for cooking



Residence







Figure A2. Reclassification of Factor Maps.

Appendix C

 Table A6. Crop Residue feedstock (ton/year) in Yangon Region Township.

Name	Rice Straw	Rice Husk	Ground Nut Straw	Ground Nut Husk	Sesame Trash	Sunflower Residue	Black Gram Crop	Black Gram Hull	Green Gram Crop	Green Gram Hull	Pigeion Crop	Pigeon Hull	Sugarcae Tops	Sugarcane Bagasse	Maize Stalk	Maize Cob
Insein	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mingaladon	1207.23	183.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hmawbi	11,308.38	1718.46	452.54	93.85	0.00	0.00	323.14	5.70	13.44	0.24	0.00	0.00	0.00	0.00	0.00	0.00
Hlegu	292,719.14	44,482.65	4398.90	912.29	43.08	0.00	2493.22	44.00	7115.42	125.57	0.00	0.00	0.00	0.00	0.00	0.00
Taikkyi	170,932.38	25,975.50	2608.66	541.01	2086.27	25.31	29,471.58	520.09	623.90	11.01	0.00	0.00	38,424.00	38,295.92	5140.65	701.70
Htantabin	355,211.87	53,979.26	690.63	143.23	2.15	0.00	5122.29	90.39	229.25	4.05	0.00	0.00	1594.20	1588.89	799.30	109.10
Shwepyithar	274.16	41.66	0.00	0.00	0.00	0.00	9.16	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hlaingtharya	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thingangyun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yankin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
South Okkalapa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
North Okkalapa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thaketa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dawbon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamwe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pazundaung	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Botahtaung	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dagon Myothit (South)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dagon Myothit (North)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.44	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Dagon Myothit (East)	22,458.52	3412.88	0.00	0.00	0.00	0.00	0.00	0.00	3.44	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Dagon Myothit (Seikkan)	15,501.94	2355.73	0.00	0.00	0.00	0.00	62.35	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mingalar taungnyunt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thanlyin	157,252.94	23,896.72	118.43	24.56	0.00	0.00	0.00	0.00	30,077.54	530.78	0.00	0.00	0.00	0.00	0.00	0.00
Kyauktan	262,814.46	39,938.23	0.00	0.00	0.00	2.26	0.00	0.00	36,466.91	643.53	0.00	0.00	0.00	0.00	0.00	0.00
Thongwa	381,007.22	57,899.22	139.50	28.93	0.00	2.00	0.00	0.00	109,480.28	1932.00	0.00	0.00	0.00	0.00	0.00	0.00

Table	A6	Cont
Iavie	AU.	COIII.

Name	Rice Straw	Rice Husk	Ground Nut Straw	Ground Nut Husk	Sesame Trash	Sunflower Residue	Black Gram Crop	Black Gram Hull	Green Gram Crop	Green Gram Hull	Pigeion Crop	Pigeon Hull	Sugarcae Tops	Sugarcane Bagasse	Maize Stalk	Maize Cob
Kayan	277,279.32	42,136.36	89.96	18.66	0.00	0.54	11.38	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Twantay	291,133.19	44,241.64	0.00	0.00	0.00	0.00	170.06	3.00	5.11	0.09	1.39	0.02	0.00	0.00	16,765.60	2288.50
Kawhmu	261,696.52	39,768.34	0.00	0.00	0.00	0.54	3.28	0.06	11.60	0.20	0.00	0.00	1263.30	1259.09	0.00	0.00
Kungyangon	285,000.43	43,309.68	0.00	0.00	0.00	0.00	0.00	0.00	7.53	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Dala	110,021.13	16,719.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seikgyikanaungto	701.33	106.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cocokyun	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyaukta da	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pabedan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lanma daw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Latha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ahlone	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kyeemyn daing	3637.47	552.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
San chaung	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hlaing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kamar yut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mayan gone	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dagon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bahan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2,900,157.63	440,718.32	8498.62	1762.54	2131.50	30.67	37,666.46	664.70	184,037.86	3247.73	1.39	0.02	41,281.50	41,143.90	22,705.55	3099.31

References

- Tun, M.M.; Juchelkova, D.; Win, M.M.; Thu, A.M.; Puchor, T. Biomass Energy: An Overview of Biomass Sources, Energy Potential, and Management in Southeast Asian Countries. *Resources* 2019, 8, 81. [CrossRef]
- Tun, M.M.; Juchelková, D. Biomass Sources and Energy Potential for Energy Sector in Myanmar: An Outlook. *Resources* 2019, 8, 102. [CrossRef]
- Sarkar, S.; Skalicky, M.; Hossain, A.; Brestic, M.; Saha, S.; Garai, S.; Ray, K.; Brahmachari, K. Management of Crop Residues for Improving Input Use Efficiency and Agricultural Sustainability. *Sustainability* 2020, 12, 9808. [CrossRef]
- 4. FAOSTAT Emissions Totals. Available online: https://www.fao.org/faostat/en/#data/GT (accessed on 24 June 2022).
- Myanmar Climate Change Master Plan (2018–2030). Available online: https://myanmar.un.org/en/25466-myanmar-climatechange-master-plan-2018-2030 (accessed on 15 November 2022).
- 6. Beňová, D.; Mareš, K.; Hutla, P.; Ivanova, T.; Banout, J.; Kolaříková, M. Energy Potential of Agri Residual Biomass in Southeast Asia with the Focus on Vietnam. *Agronomy* **2021**, *11*, 169. [CrossRef]
- Harun, S.N.; Hanafiah, M.M.; Noor, N.M. Rice Straw Utilisation for Bioenergy Production: A Brief Overview. *Energies* 2022, 15, 5542. [CrossRef]
- 8. Lee, S.Y.; Sankaran, R.; Chew, K.W.; Tan, C.H.; Krishnamoorthy, R.; Chu, D.; Show, P.L. Waste to bioenergy: A review on the recent conversion technologies. *BMC Energy* **2019**, *1*, 4. [CrossRef]
- 9. Garba, A. Biomass Conversion Technologies for Bioenergy Generation: An Introduction. Biotechnol. Appl. Biomass 2021. [CrossRef]
- Akhtar, A.; Krepl, V.; Ivanova, T. A Combined Overview of Combustion, Pyrolysis, and Gasification of Biomass. *Energy Fuels* 2018, 32, 7294–7318. [CrossRef]
- 11. Shinya, Y. The Asian Biomass Handbook A Guide for Biomass Production and Utilization Support Project for Building Asian-Partnership for Environmentally Conscious Agriculture Entrusted by Ministry of Agriculture, Forestry, and Fisheries; The Japan Institute of Energy: Tokyo, Japan, 2008.
- 12. Svazas, M.; Navickas, V.; Krajnakova, E.; Nakonieczny, J. Sustainable supply chain of the biomass cluster as a factor for preservation and enhancement of forests. *J. Int. Stud.* **2019**, *12*, 309. [CrossRef]
- Zhang, J.; Li, J.; Dong, C.; Zhang, X.; Rentizelas, A.; Shen, D. Comprehensive assessment of sustainable potential of agricultural residues for bioenergy based on geographical information system: A case study of China. *Renew. Energy* 2021, 173, 466–478. [CrossRef]
- 14. Chauhan, A.; Upadhyay, S.; Saini, G.; Senthilkumar, N. Agricultural Crop Residue Based Biomass in India: Potential Assessment, Methodology and Key Issues. *Sustain. Energy Technol. Assess.* **2022**, *53*, 102552. [CrossRef]
- 15. Aravani, V.P.; Sun, H.; Yang, Z.; Liu, G.; Wang, W.; Anagnostopoulos, G.; Syriopoulos, G.; Charisiou, N.D.; Goula, M.A.; Kornaros, M.; et al. Agricultural and livestock sector's residues in Greece & China: Comparative qualitative and quantitative characterization for assessing their potential for biogas production. *Renew. Amp. Sustain. Energy Rev.* **2022**, *154*, 111821.
- 16. Jiang, Y.; Havrysh, V.; Klymchuk, O.; Nitsenko, V.; Balezentis, T.; Streimikiene, D. Utilization of Crop Residue for Power Generation: The Case of Ukraine. *Sustainability* **2019**, *11*, 7004. [CrossRef]
- 17. Cuong, T.T.; Le, H.A.; Khai, N.M.; Hung, P.A.; Linh, L.T.; Thanh, N.V.; Tri, N.D.; Huan, N.X. Renewable energy from biomass surplus resource: Potential of power generation from rice straw in Vietnam. *Sci. Rep.* **2021**, *11*, 792. [CrossRef] [PubMed]
- 18. Dalmaijer, E.S.; Nord, C.L.; Astle, D.E. Statistical power for cluster analysis. BMC Bioinform. 2022, 23, 205. [CrossRef]
- 19. Svazas, M.; Navickas, V.; Bilan, Y.; Nakonieczny, J.; Spankova, J. Biomass Clusterization from a Regional Perspective: The Case of Lithuania. *Energies* **2021**, *14*, 6993. [CrossRef]
- Prasannakumar, V.; Vijith, H.; Charutha, R.; Geetha, N. Spatio-Temporal Clustering of Road Accidents: GIS Based Analysis and Assessment. *Procedia. Soc. Behav. Sci.* 2011, 21, 317–325. [CrossRef]
- 21. Dao, K.M.; Yabar, H.; Mizunoya, T. Unlocking the Energy Recovery Potential from Sustainable Management of Bio-Resources Based on GIS Analysis: Case Study in Hanoi, Vietnam. *Resources* **2020**, *9*, 133. [CrossRef]
- 22. Venier, F.; Yabar, H. Renewable energy recovery potential towards sustainable cattle manure management in Buenos Aires Province: Site selection based on GIS spatial analysis and statistics. *J. Clean. Prod.* **2017**, *162*, 1317–1333. [CrossRef]
- Chukwuma, E.C.; Okey-Onyesolu, F.C.; Ani, K.A.; Nwanna, E.C. GIS bio-waste assessment and suitability analysis for biogas power plant: A case study of Anambra state of Nigeria. *Renew. Energy* 2021, 163, 1182–1194. [CrossRef]
- 24. Ustaoglu, E.; Sisman, S.; Aydınoglu, A.C. Determining agricultural suitable land in peri-urban geography using GIS and Multi Criteria Decision Analysis (MCDA) techniques. *Ecol. Model.* **2021**, *455*, 109610. [CrossRef]
- 25. Günen, M.A. A comprehensive framework based on GIS-AHP for the installation of solar PV farms in Kahramanmaraş, Turkey. *Renew. Energy* 2021, 178, 212–225. [CrossRef]
- 26. Rios, R.; Duarte, S. Selection of ideal sites for the development of large-scale solar photovoltaic projects through Analytical Hierarchical Process—Geographic information systems (AHP-GIS) in Peru. *Renew. Sustain. Energy Rev.* **2021**, *149*, 111310. [CrossRef]
- Jayarathna, L.; Kent, G.; O'Hara, I.; Hobson, P. Geographical information system based fuzzy multi criteria analysis for sustainability assessment of biomass energy plant siting: A case study in Queensland, Australia. *Land Use Policy* 2022, 114, 105986. [CrossRef]

- Nantasaksiri, K.; Charoen-amornkitt, P.; Machimura, T. Integration of multicriteria decision analysis and geographic information system for site suitability assessment of Napier grass-based biogas power plant in southern Thailand. *Renew. Sustain. Energy Transit.* 2021, 1, 100011. [CrossRef]
- 29. Leander von Kameke Population Distribution in Myanmar in 2019, by State or Region. Available online: https://www.statista. com/statistics/1322796/myanmar-population-by-state-or-region/ (accessed on 24 October 2022).
- 30. Myanmar Information Management Unit Yangon 2022. Available online: https://www.themimu.info/states_regions/yangon (accessed on 24 July 2022).
- 31. Cho, A.; Belton, B.; Boughton, D. Feed the Future Innovation Lab for Food Security Policy Food Security Policy Project (FSPP) Crop Production and Profitability in Ayeyarwady and Yangon; Michigan State University: East Lansing, MI, USA, 2017.
- 32. Myanmar Information Management Unit Baseline Dataset. Available online: http://themimu.info/baseline-datasets (accessed on 24 June 2022).
- Myanmar Information Management Unit MIMU Township Profiles. Available online: http://themimu.info/township-profiles? field_doc_tx_state_regions_tid=65 (accessed on 24 June 2022).
- 34. General Administration Department 2022. Available online: http://www.gad.gov.mm/my/content/ (accessed on 24 June 2022).
- 35. Eastman, R. Uncertainty Management in GIS: Decision Support Tools for Effective Use of Spatial Data Resources. In *Spatial Uncertainty in Ecology;* Springer: New York, NY, USA, 2001; pp. 379–390.
- 36. Caprioli, C.; Bottero, M. Addressing complex challenges in transformations and planning: A fuzzy spatial multicriteria analysis for identifying suitable locations for urban infrastructures. *Land Use Policy* **2021**, *102*, 105147. [CrossRef]
- 37. Saaty, T.L. A scaling method for priorities in hierarchical structures. J. Math. Psychol. 1977, 15, 234–281. [CrossRef]
- Koopmans, A.; Koppejan, J. Agricultural and forest residues-generation, utilization and availability. *Reg. Consult. Modern Appl. Biomass Energy* 1997, 6, 10.
- Zheng, B.; Campbell, J.B.; de Beurs, K.M. Remote sensing of crop residue cover using multi-temporal Landsat imagery. *Remote Sens. Environ.* 2012, 117, 177–183. [CrossRef]
- 40. Esri Land Cover. Available online: https://livingatlas.arcgis.com/landcover (accessed on 24 July 2021).
- 41. USGS Earth Explorer. Available online: https://earthexplorer.usgs.gov/ (accessed on 24 July 2021).
- 42. Myanmar Information Management Unit Myanmar Township Boundaries MIMU v9.3. Available online: http://geonode. themimu.info/layers/geonode%3Ammr_polbnda_adm3_mimu_250k (accessed on 24 June 2022).
- 43. Geofabrik GmbH Open StreetMap Data Extracts. Available online: http://download.geofabrik.de/asia/myanmar.html (accessed on 24 July 2022).
- 44. OpenDevelopment Mekong River Networks of Myanmar. Available online: https://data.opendevelopmentmyanmar.net/en/ dataset/river-networks-of-myanmar (accessed on 22 June 2022).
- Myanmar Information Management Unit Myanmar Railway Network 2022. Available online: http://geonode.themimu.info/ layers/geonode%3Ammr_rlwl_mimu_250k (accessed on 24 July 2022).
- 46. Yangon International Airport. 2022. Available online: https://yangonairport.aero/index.php/en/ (accessed on 1 August 2022).
- 47. Open Development Mekong Lower Mekong Countries Protected and Heritage Areas. Available online: https://data. opendevelopmentmyanmar.net/en/dataset/greater-mekong-subregion-protected-and-heritage-areas (accessed on 21 June 2022).
- 48. Dartmouth Flood Observatory Myanmar Current Flood Conditions, Southern Myanmar. Available online: https://floodobservatory.colorado.edu/Myanmar.html (accessed on 21 June 2021).
- Institute for Earth Observation Myanmar. 2020. Available online: https://geomap.institute/course-category/remote-sensing/ (accessed on 10 January 2021).
- 50. Myanmar Information Management Unit Myanmar Land Use. 2000. Available online: https://geonode.themimu.info/layers/geonode%3Amyanmar_land_use (accessed on 20 June 2021).
- 51. Open Development Myanmar Myanmar—Existing Grid Medium Voltage Line Data. Available online: https://data. opendevelopmentmyanmar.net/en/dataset/myanmar-existing-grid-medium-voltage-line-data (accessed on 21 June 2022).
- 52. Open Development Myanmar Myanmar—High Voltage Transmission Lines. Available online: https://data.opendevelopmentmyanmar. net/en/dataset/myanmar-high-voltage-transmission-lines (accessed on 21 June 2022).
- Bhattacharya, S.C.; Pham, H.L.; Shrestha, R.M.; Vu, Q.V. CO₂ emissions due to fossil and traditional fuels, residues and wastes in Asia. In *Workshop on Global Warming Issues in Asia*; The Asian Institute of Technology: Bangkok, Thailand, 1993; pp. 29–31.
- 54. Barnard, G.; Kristoferson, L. Agricultural Residues as Fuel in the Third World. In *Energy Information Program, Earthscan;* Earthscan-The Beijer Institute: London, UK, 1985.
- Okello, C.; Pindozzi, S.; Faugno, S.; Boccia, L. Bioenergy potential of agricultural and forest residues in Uganda. *Biomass Amp. Bioenergy* 2013, 56, 515–525. [CrossRef]
- Avcioglu, A.O.; Dayioglu, M.A.; Turker, U. Assessment of the energy potential of agricultural biomass residues in Turkey. *Renew.* Energy 2019, 138, 610–619. [CrossRef]
- 57. Swain, B.; Blümmel, M.; Jones, C.S.; Rahman, H. Demand and Availability of Feed Resources for Large Ruminants across Different Districts of Odisha; ILRI Project Report; ILRI: Nairobi, Kenya, 2020.
- Hýsková, P.; Hýsek, Š.; Jarský, V. The Utilization of Crop Residues as Forest Protection: Predicting the Production of Wheat and Rapeseed Residues. *Sustainability* 2020, 12, 5828. [CrossRef]

- Khan, M.M.; Vaezi, M.; Kumar, A. Optimal siting of solid waste-to-value-added facilities through a GIS-based assessment. *Sci. Total Environ.* 2018, 610–611, 1065–1075. [CrossRef] [PubMed]
- Johar, A.; Jain, S.S.; Garg, P.K. Land suitability analysis for industrial development using GIS Land suitability analysis for industrial development using GIS. J. Geomat. 2013, 7, 101–106.
- 61. Fataei, E.; Erdi, M.A.; Farhadi, H.; Mohammadian, A. Industrial State Site Selection Using MCDM Method and GIS in Germi, Ardabil, Iran. *J. Ind. Intell. Inf.* 2015, *3*, 324–329. [CrossRef]
- 62. Rikalovic, A.; Cosic, I.; Lazarevic, D. GIS Based Multi-criteria Analysis for Industrial Site Selection. *Procedia Eng.* 2014, 69, 1054–1063. [CrossRef]
- 63. Beshr, A.A.A.; El-Mewafi, M.; Alzamili, H.H.; Awad, A.; Alzamili, H.H.; El-Mewafi, M.; Beshr, A.M.; Awad, A.; Hadeal, M.; Alzamili, H.; et al. GIS Based Multi Criteria Dicesion Analysis for Industrial Site Selection in Al- Nasiriyah City in Iraq Deformation study View project Reservoir analysis View project GIS Based Multi Criteria Dicesion Analysis for Industrial Site Selection in Al-Nasiriyah City in Iraq. *Int. J. Sci. Amp. Eng. Res.* 2015, *6*, 1330–1337.
- 64. Ramya, S.; Devadas, V. Integration of GIS, AHP and TOPSIS in evaluating suitable locations for industrial development: A case of Tehri Garhwal district, Uttarakhand, India. J. Clean. Prod. 2019, 238, 117872. [CrossRef]
- 65. The Republic of the Union of Myanmar, Department of Population Ministry of Immigration and Population The 2014 Myanmar Population and Housing Census, Census Report Volume 3-L, Yangon Region; Department of Population Ministry of Labour: Nay Pyi Taw, Myanmar, 2015.