Development of contemporary pepper crop (*Piper nigrum* L.) in West Lampung Regency, Indonesia

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Abstract. Pepper crop has been developed and established in the West Lampung Regency. In line with contemporary agriculture’s with a tendency for standardized management supported by modern communication technology, the current agriculture practice should adopt the situation. In preparation, we need to develop a center of pepper development area through spatial planning. Several factors in developing the main region are actual dominant pepper crops, land suitability, current spatial planning, socio-economy of farmers, communication infrastructure, others that are evaluated using spatial multi-criteria approach. The result showed the potential area as a central area of pepper development, with some prerequisites of development of better agriculture practice for precision farming, and the improvement of farmer using a current mobile phone to access good agricultural practices and the potential market.

Keywords: pepper, development area, multi-criteria spatial, digital infrastructure

1. Introduction
Agriculture-based economic development has an impact straightforwardly or by implication on the national economy [1]. One of the sub-sectors in agriculture that contributes significantly to the national economy is the plantation sub-sector. The plantation sub-sector became one of the main pillars of the positive growth of the agricultural sector's GDP in the third quarter of 2020, amounting to 28.59% or IDR 163.49 trillion [2]. A threefold increase in agricultural exports is targeted by the Minister of Agriculture through the Triple Exports Movement or “Gratieks” program specifically for the plantation sub-sector on strategic commodities such as palm oil, coffee, rubber, pepper, cocoa, cloves, nutmeg, cashew, and vanilla [2].

One of the export commodities from the plantation sub-sector that has an important role in the economy as a source of foreign exchange and livelihood for farmers is pepper [3]. Pepper exports in 2016 amounted to 33,645 tons (provisional figures) [4]. BPS also noted that in 2012-2016, pepper contributed an export value of more than USD 400 million [5]. In 2016, the national pepper production reached 53.100 tons, thus placing Indonesia as the second-largest pepper producer after Vietnam [6]. The largest export supply of pepper in Indonesia comes from Bangka Belitung province, which known as Muntok White Pepper, and Lampung province, which known as Lampung Black Pepper [7]. West Lampung Regency is one of the pepper production centers in Lampung Province, which is widespread...
in almost all regions [8]. Although Lampung Province has a large pepper area, the pepper productivity is still lower than other provinces with smaller areas, such as Bengkulu and West Kalimantan Provinces. The low productivity of pepper is influenced by several factors, namely: the use of short shoots, pepper seeds from hanging vines/worms, sub-optimal pruning both for pepper and its spikes, and little fertilizer and weed control [9]. The use of tall shoots (> 5 m) pruned three times a year joined by adjusted treatment can increase the productivity of national pepper.

Increasing pepper productivity can be achieved through agricultural technology innovation 4.0, which is considered the key to agricultural restructuring and solutions in overcoming the quality of agricultural products. Agriculture 4.0 is high-tech agriculture to improve quality and efficiency and satisfy progressively varied customer needs [10]. Pepper development in agricultural era 4.0 should be adjusted with the community and regional development that involves various factors, such as social, economic, cultural, and technological factors, which interact with each other in the development process [11]. Following the government's plan in Law Number 39 of 2014 concerning plantations that plantation development is carried out in an integrated manner with an area approach that is functionally connected between cities/districts, provinces, and nationalities. In line with the development of current agricultural conditions, which interact a lot with the information technology and the possibility of policy changes, the proposed area to be used as a pepper development center is needed to determine the main area for pepper development. Hence, the objective of this research was to determine the pepper development area in West Lampung Regency by using Spatial Multicriteria Evaluation.

2. Research method
2.1 Study area
This study was conducted in West Lampung Regency, which is located between 40°47'16" - 50°56'42" South Latitude and 103°35'08" - 104°33'51" East Longitude. The regency, which has the capital city of Liwa, administratively covers 15 sub-districts, five districts, and 131 villages or "pekon" with a total area of 2,102.45 km$^2$. The administrative map of the West Lampung Regency is presented in Figure 1.

![Figure 1. Study area.](image)

2.2 Data collection
Field surveys and interviews with the government officers of the Plantation and Livestock Service Office in West Lampung Regency were conducted to collect primary data. At the same time, the secondary data such as soil map, forest area map, and spatial planning for West Lampung Regency were used to support the analysis.
2.3 Pepper development area analysis

Determination of the appropriate area to be developed as a Pepper Development Area is approached with the Spatial Multicriteria Evaluation (MCE) model, solving the problem of suitability (the best location or the most likely location of several phenomena) uses several layers of information. Each layer that contributes to the solution is defined as a criterion. There are two MCE approaches used in this study to determine the most suitable model, namely Boolean Combination and Weighted Linear Combination.

The first MCE model is the Boolean combination model, where each criterion is assumed to have the same effect on the results/solutions, while the scores for each class in each criterion are set with a clear boundary of two Boolean scores, namely appropriate or inappropriate. The Boolean combination criteria is shown in Table 1.

| Land Availability | Land Suitability | Signal Strength | Code   | Results |
|-------------------|------------------|-----------------|--------|---------|
| Available Land    | Suitable (1)     | Strong (X)      | A1X    | Priority 1 |
|                   |                  |                 | A1Y    | Priority 2 |
|                   |                  |                 | A2X    | Priority 3 |
|                   |                  |                 | A2Y    | Priority 4 |
| Potential Land    | Conditionally    | Weak (Y)        | B1X    | Priority 5 |
| Available (B)     | Suitable (2)     |                 | B1Y    | Priority 6 |
|                   |                  |                 | B2X    | Priority 7 |
|                   |                  |                 | B2Y    | Priority 8 |

The second MCE model uses the Weighted Linear Combination model, where each criterion is assumed to have a different weight of influence on the results. The weight values are compared between criteria using the Rank Order Centroid (ROC) weighting method. In comparison, the score values are ranged with a certain scale in each class of criteria using expert judgment, which in this study uses a scale of 1-5. In this case, criterion-1 is the highest priority compared to criterion 2, as well as criterion 2 is the highest priority when compared to criterion 3, then the same steps are carried out until the lowest priority criterion [12]. In general, the ROC weighting can be formulated as follows:

\[ W_k = \frac{1}{k} \sum_{i=1}^{k} \left( \frac{1}{i} \right) \]  \hspace{1cm} (1)

Where \( W_k \) is \( j \) attribute weighting value, \( k \) is a number of attributes, and \( i \) is an attribute priority sequence value. The criteria used to consist of land use, land suitability, land availability, number of plantation farmer groups, and signal strength of communication devices (mobile phones). The following figure shows the flowchart of weighted linear combination analysis.

![Figure 2. The weighted linear combination process.](image)
The value of weights and scores for each criterion are shown in Table 2. The final result shows development priorities where a score of 5 means priority 1, score 4 priority 2, score 3 priority 3, score 2 priority 4, and score 1 priority 5.

### Table 2. Weighted linear combination criterion.

| No | Criterion | Class               | Weight | Scores |
|----|-----------|---------------------|--------|--------|
| 1  | Land Use  | Pepper              | 0.45   | 5      |
|    |           | Not Pepper          |        | 1      |
| 2  | Land Suitability | S1         | 0.25   | 5      |
|    |           | S2                  |        | 3      |
|    |           | S3                  |        | 3      |
|    |           | N                   |        | 1      |
| 3  | Land Availability | Available Land | 0.15   | 5      |
|    |           | Potential Land Available |    | 3      |
|    |           | Land Not Available  |        | 1      |
| 4  | Number of plantation farmer groups | 97-120 | 0.10   | 5      |
|    |           | 73-96               |        | 4      |
|    |           | 49-72               |        | 3      |
|    |           | 25-48               |        | 2      |
|    |           | 1-24                |        | 1      |
| 5  | The signal strength of communication | Strong | 0.05   | 5      |
|    |           | Weak                |        | 3      |
|    |           | No Signal           |        | 1      |

3. Results and discussion

#### 3.1 Pepper development area

The results of this study were obtained from two different analyses, namely the Boolean and weighted linear combination technique on the pepper area in West Lampung Regency. There are five classes of development areas, namely priority 1, priority 2, priority 3, priority 4, and priority 5. Priorities 1 and 2 are areas that have good potential for pepper development. Priority 3 areas can be a pepper development area but has a limiting factor with a moderate level of difficulty. The priority 4 areas of pepper development have a severe level of difficulty limiting factor. The last area is priority 5, which has the lowest weighting results or is unsuitable for pepper development.

The result of the Boolean technique in Figure 3 shows that the distribution areas of priority 1 and 2 is dominantly located in the east to the middle region of West Lampung Regency, especially in Way Tenong Sub-district covering an area of 933 ha (priority 1) and 1,851 ha (priority 2) (Table 3). These areas were marked in dark green and light green (Figure 3).

![Figure 3. Pepper development area with the Boolean technique.](image-url)
Compared to the weighted linear combination result (Figure 4), the distribution of priority 1 and 2 areas was spread in the eastern and central areas of West Lampung Regency. It is also located in Way Tenong Sub-district with an area of 3,401 ha (Priority 1) and 386 ha (Priority 2) (Table 3). According to the Plantation and Livestock Service Office of West Lampung Regency, Way Tenong Sub-district has the largest pepper area. Thus, Way Tenong Sub-district can be recommended as a pepper center development area for West Lampung Regency.

From both analysis techniques, priorities 1 and 2 were chosen to be potential pepper development areas because they are suitable with the limiting factors and the spatial planning designation. These two areas also have a sufficient number of farmer groups and strong signal strength. Meanwhile, priority 3 and 4 have some moderate difficulties of limiting factors spread almost all over the region. Another priority area, priority 5, is dominated by protected forest, which is an area of Bukit Barisan National Park located in the western and northern part of West Lampung Regency.

Table 3. The total priority area of pepper development using the Boolean and the weighted linear combination.

| Sub-districts         | Technique analysis | Priority 1 | Priority 2 | Priority 3 | Priority 4 | Priority 5 |
|-----------------------|--------------------|------------|------------|------------|------------|------------|
| Air Hitam             | B                  | 71         | 2,035      | 0          | 0          | 1,445      |
|                       | W                  | 2,072      | 1,065      | 65         | 328        | 21         |
| Balik Bukit           | B                  | 0          | 756        | 0          | 645        | 761        |
|                       | W                  | 665        | 1,126      | 34         | 260        | 78         |
| Bandar Negeri Suoh    | B                  | 468        | 1,945      | 14         | 325        | 180        |
|                       | W                  | 675        | 1,094      | 43         | 218        | 115        |
| Batu Brak             | B                  | 0          | 2,674      | 0          | 14         | 1,293      |
|                       | W                  | 2,630      | 830        | 89         | 431        | 0          |
| Batu Ketulis          | B                  | 0          | 2,333      | 0          | 47         | 2,650      |
|                       | W                  | 1,992      | 2,234      | 78         | 645        | 82         |
| Belalau               | B                  | 0          | 1,764      | 0          | 0          | 2,136      |
|                       | W                  | 1,642      | 1,544      | 215        | 399        | 101        |
| Gedung Surian         | B                  | 0          | 2,130      | 0          | 0          | 2,364      |
|                       | W                  | 2,287      | 1,831      | 43         | 218        | 115        |
| Kebun Tebu            | B                  | 0          | 370        | 0          | 255        | 1,382      |
|                       | W                  | 675        | 1,094      | 14         | 159        | 67         |
| Lumbok Seminung       | B                  | 0          | 0          | 19         | 45         | 56         |
|                       | W                  | 41         | 47         | 0          | 21         | 11         |
| Pagar Dewa            | B                  | 0          | 814        | 0          | 1,136      | 4,473      |
|                       | W                  | 1,207      | 4,261      | 36         | 834        | 86         |
3.2 Kappa value of the results between Boolean and weighted linear combination technique

The comparison results between Figure 3 and Figure 4 show differences in terms of priority results. According to [12], the difference in the distribution of priority results is influenced by the formula or calculation technique, and the Boolean technique is done using algebraic logic, while the weighted overlay technique uses an algorithm formula to find suitability. Thus, the Boolean technique will produce more data because it includes all the appropriate data. After all, all data is considered to have weight. Meanwhile, in the weighted linear combination technique, the input data have different weights according to their influence and importance. Therefore, the priority 5 area from Boolean technique has a larger area compared to the priority 1 area from weighted linear combination’s result.

The results of the Boolean and weighted linear combination analysis technique were tested for the Kappa value to see the similarity. Tests were carried out using IDRISI SELVA software. The results show that a kappa value of 88.18%, which means that the two results of the analysis have similarities.

3.3 Comparison of the results of priority area with the spatial planning

The results of the two analyzes were then equally compared with the spatial planning of the West Lampung Regency. The results of Boolean analysis on suitability for priorities 1, 2, and 3 are following the spatial planning designation, namely plantations with an area of 1,004 ha, 17,790 ha, and 300 ha, respectively (Table 4). The criteria in the Boolean method are assumed to have the same effect as the appropriate and inappropriate determination.

Table 4. Directions for developing pepper area from a Boolean analysis of the spatial planning.

| Spatial Plan | Priority 1 (ha) | Priority 2 (ha) | Priority 3 (ha) | Priority 4 (ha) | Priority 5 (ha) | Total (ha) |
|--------------|----------------|----------------|----------------|----------------|----------------|------------|
| Horticulture | 0              | 0              | 0              | 1,149          | 400            | 1,548      |
| Protected forest | 0              | 0              | 0              | 0              | 12,760         | 12,760     |
| Slope >40% | 0              | 0              | 0              | 0              | 117            | 117        |
| Settlement | 0              | 0              | 0              | 0              | 20             | 20         |
| Plantation | 1,004          | 17,790         | 300            | 498            | 4,620          | 24,212     |
| Flood area | 0              | 1              | 0              | 0              | 447            | 447        |
| Wetland crops | 0              | 0              | 16             | 547            | 126            | 690        |
| Dryland crops | 0              | 1              | 2              | 983            | 137            | 1,124      |
| TNBBS | 0              | 0              | 0              | 0              | 6,392          | 6,392      |
| Total | 1,004          | 17,792         | 319            | 3177           | 25,019         | 47,311     |

Meanwhile, the weighted linear combination technique shows that the results are quite diverse, but the majority are still following the plantations allocation in the spatial planning. The plantations on priority 1 covering an area of 18,758 ha (Table 5). While the plantations area in priority 2 was covering
10,425 ha and is directed to protected forest, so it cannot be utilized as a development area for pepper. The weighted linear combination technique uses a scoring range assuming that the criteria used have different effects. However, the Boolean analysis has more advantages than weighted linear combination analysis in terms of compatibility with the spatial plan.

In general, pepper development areas from Boolean analysis and weighted linear combination analysis show good results. However, it is necessary to develop more details on socio-economic conditions at the sub-district and village levels so that more detailed results are obtained regarding problems that may occur. The signal strength criteria used in this study must refer to the use of the internet of pepper development, especially in the marketing section.

**Table 5.** Directions for developing pepper area from a weighted analysis on the spatial planning.

| Spatial Plan         | Priority 1 | Priority 2 | Priority 3 | Priority 4 | Priority 5 | Total (ha) |
|----------------------|------------|------------|------------|------------|------------|------------|
| Horticulture         | 439        | 879        | 6          | 219        | 5          | 1,548      |
| Protected forest     | 372        | 10,425     | 166        | 1,322      | 476        | 12,761     |
| Slope >40%           | 1          | 91         | 0          | 19         | 6          | 117        |
| Settlement           | 0          | 15         | 0          | 5          | 0          | 20         |
| Plantation           | 18,758     | 2,456      | 862        | 2,038      | 100        | 24,215     |
| Flood area           | 24         | 338        | 0          | 84         | 0          | 447        |
| Wetland crops        | 399        | 165        | 0          | 120        | 6          | 689        |
| Dryland crops        | 238        | 677        | 0          | 199        | 10         | 1,123      |
| TNBBS                | 243        | 5086       | 0          | 824        | 239        | 6,393      |
| **Total**            | **20,474** | **20,132** | **1,035**  | **4,830**  | **843**    | **47,314** |

**3.4 Pepper development in the agricultural era 4.0**

Developments in the agricultural era 4.0 can refer to the digitalization of marketing in pepper plantations. Digital marketing is expected to make farmers involved in market access and make more choices in selling their crops so that farmers can get maximum profit. This could be one solution to the long-selling distribution chain and farmer’s dependence on middlemen, which causes the selling price to be inappropriate or low [13]. Thus, preparation is needed to enter this marketing digitalization stage, such as the readiness of farmers to access online markets, internet signal strength in accessing information, and managers or third parties who can accommodate farmers in selling their crops online. Preparation before entering the marketing digitalization stage is very important because the main problems related to digital marketing are limited capabilities from third parties, weak infrastructure and market information, and narrow distribution of agricultural products [14, 15, 16].

**4. Conclusion**

Priority 1 and 2 from the weighted linear combination technique are suitable for pepper development covering 20,474 ha and 20,131 ha. Boolean analysis technique shows priority results 1 and 2 with an area of 1,004 ha and 17,792 ha. Both priorities are very suitable for the pepper development areas, which is dominantly located in Way Tenong Sub-district. In general, the pepper area development map from Boolean analysis and weighted overlay show good results. However, the boolean analysis has advantages over-weighted linear combination analysis in terms of compatibility with the spatial plan. The methods still need to be developed in more detail regarding socio-economic conditions at the sub-district and village levels so that more detailed results are obtained regarding the problems that occur. As in the signal strength criteria used in this study, it must refer to the improvement of farmers using a current mobile phones to access good agricultural practices and the potential market.
References

[1] Mangiring, Z and W 2017 Analisis Biaya Transaksi pada Kelembagaan Pertanian Gapoktan Penerima Program Pengembangan Usaha Agribisnis Pedesaan (PUAP) di Desa Raman Aji Kecamatan Raman Utara Kabupaten Lampung Timur J. Pertanian Terapan 17(3) pp 186–196

[2] Directorate General of Plantations 2020 Plantation export opportunities still survive Jakarta: [online https://ditjenbun.pertanian.go.id/peluang-ekspor-perkebunan-masih-bertahan/]

[3] Sumantri B, Priyono B S and Isonita M 2004 Analisis kelayakan finansial usahatani lada (Piper nigrum L.) di Desa Kunduran Kecamatan Ulu Musi Kabupaten Lahat Sumatera Selatan J. Ilmu-Ilmu Pertanian Indonesia 6(1) pp 32–42

[4] International Pepper Community 2017 Pepper Statistical Yearbook 2017 (Jakarta: International Pepper Community)

[5] Ministry of Trade 2017 Pepper day 2017: momentum for the rise of the glory of Indonesian pepper [online http://www.kemendag.go.id/files/pdf/2017/10/04/hari-lada-2017-momentum-bangkitnya-kejayaan-lada-indonesia-id0-1507135013.pdf]

[6] International Trade Center 2017 Trade map-trade statistic for international business development. [online https://www.trademap.org]

[7] Directorate General of Plantations 2016 Pengembangan Tanaman Semusim dan Rempah (Jakarta: Ministry of Agriculture)

[8] Daras U 2015 Strategi peningkatan produktivitas lada dengan tajar tinggi dan pemangkasan intensif serta kemungkinan adopsinya di Indonesia J. Perspektif chapter 14(2) pp 113-124

[9] Central Bureau of Statistic 2018 Lampung Barat Regency in Figures (Lampung: BPS Lampung Barat Regency)

[10] European Agricultural Machinery 2017 Digital Farming: what does it really mean? (Brussels: CEMA)

[11] Luu T D and Nguyen T K H 2017 The revolution of agriculture 4.0 and sustainable agriculture development in Vietnam. Proc. Int. Conf. on Industrial Revolution 4.0: Opportunities and Challenges to Vietnam's Economic Development (Hanoi) p 318

[12] Ukhti F, Manurug Z K and Mahendra MD 2021 Perbandingan teknik Boolean dengan weighted overlay dalam analisis potensi longsor di Banjarmasin J. Geosains and Remote Sensing (JGRS) 2(1) pp 25-32

[13] Utami D P 2020 Pengenalan Digital Marketing dalam Pemasaran Produk Pertanian untuk Petani Milenial Desa Wonotulus Kecamatan Purworejo Kabupaten Purworejo Proc. Conf. on Peningkatan Daya Saing Hasil Pertanian Menuju Revolusi Industri 4.0 (Mataram) p 25

[14] Anggraini N, Sutarni, Fatih C, Zaini M, Analianasari and Humaidi E 2020 Digital marketing produk pertanian di Desa Sukawaringin Kecamatan Bangunrejo Kabupaten Lampung Tengah J. Pengabdian Nasional 1(1) pp 36-45

[15] Asriani 2011 Pemanfaatan internet marketing dalam pemasaran produk unggulan petani provinsi Gorontalo J. Komunikasi KAREBA 3(1) 249-257

[16] Suweantara E, Martana I G S A, Suarya A and Widiartha I M 2017 Aplikasi E-Tani sebagai strategi peningkatan kualitas dan kesejahteraan para petani Proc. Conf on Internet of things (IOT) and big data: Teknologi, tantangan, dan peluang (Bali) p 142