Satellite image processing for precision agriculture and agroindustry using convolutional neural network and genetic algorithm

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Abstract. Translating satellite imagery to a useful data for decision making during this time are usually done manually by human. In this research, we are going to translate satellite imagery by using artificial intelligence method specifically using convolutional neural network and genetic algorithm to become a useful data for decision making, especially for precision agriculture and agroindustry. In this research, we are focused on how to made a sustainable land use planning with 3 objectives. The first is maximizing economic factor. Second is minimizing CO2 emission and the last is minimizing land degradation. Results show that by using artificial intelligence method, can produced a good pareto optimum solutions in a short time.

1. Introduction
Bogor Agricultural University (IPB) and Indonesia National Institute of Aeronautics and Space (LAPAN) today had been cooperation launched a satellite called as LAPAN-IPB Satellite. The challenge now is how to translate image from satellite to become a useful data for decision making, especially for precision agriculture and agroindustry.

During this time, translating satellite imagery to a useful data for decision making usually done manually by human. In this research, we are going to translate satellite imagery by using artificial intelligence (AI) method specifically using convolutional neural network (CNN) and genetic algorithm (GA). One example application in satellite image processing is to develop green and sustainable biodiesel industry. The design process need to be start from top level such as land preparation, middle level such as industry and also in bottom level such as consumer.

In this research, we are focused on how to make a sustainable land use planning with 3 objectives. The first is maximizing economic factor. Second is minimizing CO2 emission and the last is minimizing land degradation. The input of land use planning is satellite imagery, and this input will be give CNN and GA and those AI method will process intelligently. Through the process we hope, we can obtain a good solution that meets the three criteria above.

Many works on using CNN for satellite image processing can achieve high accuracy between 75% until 91% [1]. CNN basically inspired by biological neural network. It is reproduce some of its functions by using simple but massively interconnected processing units neurons.

Genetic Algorithms is a searching and optimization technique that mimics the process of evolution and genetic structural change in living organisms [2][3][4]. It is, therefore, often called as evolutionary algorithms. In this study, multiobjective (multicriteria) optimization was done. Multiobjective
optimization is an optimization of more than one objective functions where conflicts among those functions is likely to occur [5][6].

Continuous use of fossil fuel in the world has caused its scarcity. This has led to a situation where a search for alternative renewable fuel sources from plants (bioenergy) needs to be done [7]. Bioenergy is a source of renewable energy potential to reduce carbon emission compared to fossil fuel. However, increasing bioenergy production might cause land use change (LUC) and an increase in CO2 emission to the atmosphere [8]. Indonesia has a great potential of bioenergy production as this country has a total land size of 188.20 million hectares with 100.80 hectares of it is suitable for farming land [9]. Therefore, good and optimal planning of land utilization is really needed in order to improve bioenergy productivity in Indonesia.

Oil palm is one of the potential plants for bioenergy production. Oil palm plantations have been extensively developed not only by state-owned companies but also by private companies and smallholder estate owners [10]. According to [10] and [11], Indonesia is the biggest palm oil producer in the world. Therefore, planning in land utilization for biodiesel industry is important in order to reach the objectives which do not only focus on the economic aspect but also pay attention to environmental conservation.

Good and right land utilization could help economic development. Land utilization planning is needed for optimal land utilization. The problem of land utilization is so complex that a smart computation technique is needed for optimal land utilization planning [10][12][13].

Genetic algorithm has been used to solve problems in land utilization. [14] used multi-objective evolutionary algorithm (MOEA) for land use allocation. [15] also used non-dominated sorting genetic algorithms (NSGA-II) to optimize spatial multi-objective in land use allocation [16] also used NSGA-II for solving multi-objective land use problems in Tongzhou, China. [13] also had been done a land use optimization in region in China, but with different objective function from [16].

Results with numerical example shows CNN and GA can produced a good pareto optimum solutions in a short time. In our previous research [17] we had not considered a spatial aspect. But, in this research we added a spatial aspect such as height of land. So the present research become more complex.

2. Methodology

![Methodology Diagram]

First, Image from satellite was processed by convolutional neural network for classifying plant types in land area. After that, data was modeled as a grid form and land types and land high data also added to grid form. Next, the grid form model was evaluated to assess the existing value of 3 objectives. After an assessment, genetic algorithm will take an optimization process to produce a final best solutions.
2.1. Chromosome modeling

The Chromosome are modeled in 2 dimensonal matrix form according to grid form which had been created before. There are 3 chromosome which had been modeled, land type chromosome, land high chromosome and plant type chromosome. For land type and land high chromosome, there are several types of value which positions are not change. For plant types chromosome there are 3 value which is random between 1 to 3 as in figure 3 below.

| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |
| 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 | 1-3 |

Figure 2. Plant types chromosome

2.2. Objective functions

In this paper, there were three objective functions on which optimizations were done. These included profit factor obtained and modified from the study of Shaygan [15], CO2 emission absorption function modified from [14], and soil fertility function obtained from the modification of [15] and [14]. Chromosome representation was adopted from the ones of Shaygan [15]. Plant types, land types and land high types were limited into 3, 5 and 4, respectively. In order to show system’s capability, data in the form of numerical examples were used.

2.2.1 Profit factor function

In this function formulation, Z1 was defined as maximizing profit factor where \( Ec_{lu,lh,i,j} \) was the profit factor from the use of \( lu \) land type and \( lh \) land high applied in \((i, j)\) unit. \( Ru \) was the number of rows in land use unit and \( Cu \) was the number of columns in land use unit.

\[
Z1 = \text{Max} \sum_{lu=1}^{LU} \sum_{lh=1}^{LH} \sum_{i=1}^{Ru} \sum_{j=1}^{Cu} Ec_{lu,lh,i,j}
\]  

(1)

2.2.2 Carbon sequestration factor function

Second function is minimizing carbon emission, so it mean we have to maximizing carbon sequestration.

In this function formulation, Z2 was defined as maximizing CO2 sequestration factor where \( Car_{lu,lh,i,j} \) was the sequestration factor from the use of \( lu \) land type and \( lh \) land high applied in \((i, j)\) unit. \( Ru \) was the number of rows in land use unit and \( Cu \) was the number of columns in land use unit.

\[
Z2 = \text{Max} \sum_{lu=1}^{LU} \sum_{lh=1}^{LH} \sum_{i=1}^{Ru} \sum_{j=1}^{Cu} Car_{lu,lh,i,j}
\]  

(2)
2.2.3 Soil fertility factor function

Third function is minimizing land degradation, so it means we have to maximizing land fertility. In this function formulation, $Z_3$ was defined as maximizing land fertility factor where $F_{lu,lh,i,j}$ was the land fertility factor from the use of $lu$ land type and $lh$ land high applied in $(i, j)$ unit. $Ru$ was the number of rows in land use unit and $Cu$ was the number of columns in land use unit.

$$Z_3 = \text{Max} \sum_{lu=1}^{LU} \sum_{lh=1}^{LH} \sum_{i=1}^{Ru} \sum_{j=1}^{Cu} F_{lu,lh,i,j}$$  \hspace{1cm} (3)

2.3. Non-dominated sorting

Non-dominated sorting is one of the multi-objective genetic algorithm processes which gives a rank to each individual based on their objective functions [14].

2.4. Crowding distance

After rank has been given to each individual, crowding distance value also added to each individual to know the diversity of population [14] [18].

2.5. Binary selection tournament

After the process which has been done before, the selection process will be conducted according to following criteria:

- If individuals are located in the same front, then choose the bigger value of crowding distance.
- If individuals are located in different ranks, then choose the lower rank (better rank).

2.6. Crossover

Crossover type which has been used in this research is uniform crossover [19] but it had been modified for 2 dimension chromosome case, which has been adapted based on Bui and Moon crossover principle [20].

![Crossover operator](image)

**Figure 3.** Crossover operator

2.7. Mutation

Mutation which has been used in this research is swap mutation [21]. But, it has been modified by change the swap to generate random number.

![Mutation operator](image)

**Figure 4.** Mutation operator
2.8. Recombination
Recombination is a process to store all best individual in multi-objective genetic algorithm generation process. Parent and offspring are combined, so the size of population become 2 times larger. After that, each individual are given a rank and crowding distance value, then population will be cut half. Cutting at the last individual, considering a crowding distance value. Individual that contain higher value will be take to the next population [18].

![Figure 5. Recombination](image)

3. Results and Discussions
The following figures shows traveling of individual in multiobjective genetic algorithm generation. Black filled circles are the non dominated individual in generation, black rings are indicates a dominated individual in generation.

![Figure 6. Plot initial population](image)
The following figures are comparing initial population with final population. So we can see the population movement. Black filled circles are indicates final generation, black rings are indicates initial population.

![Figure 7. Initial and final generation](image)

4. Conclusions
Based on results we got, at the first generated initial population, we can see most of individual still spread randomly and number of non dominated individual still smaller than dominated individual. At the end of generation, population move intelligently to optimum position and we can see all individual are non dominated in final generation, it means genetic algorithm succeed optimizing a problems.

So it can be concluded that satellite imagery for precision agriculture and agroindustry problem can be well solved using convolutional neural network and genetic algorithm

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