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

Firdaus[1*], Y Arkeman[1,2] , A Buono[1] and I Hermadi[1]

[1] Departement of Computer Science, Bogor Agricultural University, Indonesia
[2] Departement of Agroindustrial Technology, Bogor Agricultural University, Indonesia

E-mail: firdaus.prawiradisastra@gmail.com

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 CO_2 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 made a sustainable land use planning with 3 objectives. The first is maximizing economic factor. Second is minimizing CO_2 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 multiobjective in land use allocation [16] also used NSGA-II for solving multiobjective landuse problems in Tongzhou, China. [13] also had been done a landuse 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

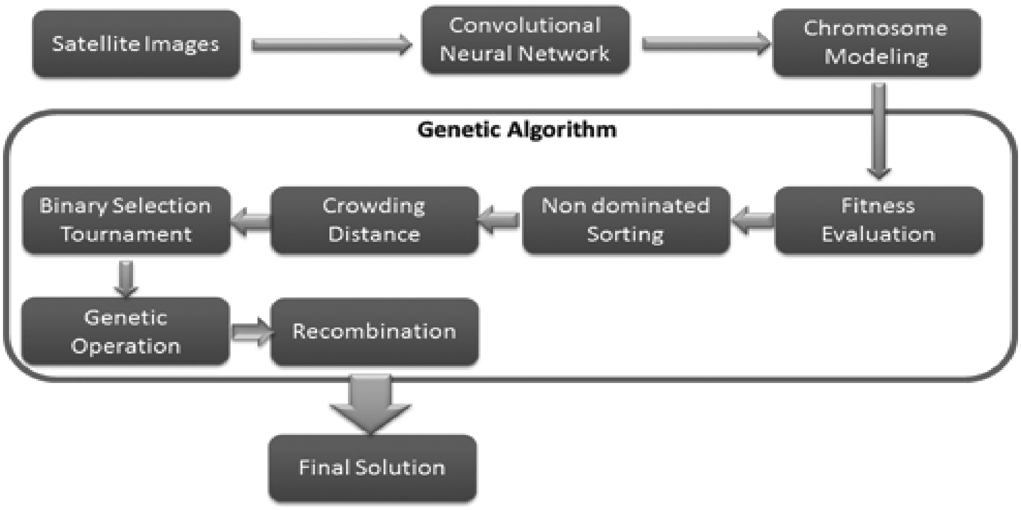

Figure 1. Methodology

First, Image from satellite was processed by convolutional neural network for clasifying 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	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.

$$Z1 = Max \sum_{lu=1}^{LU} \sum_{lh=1}^{LH} \sum_{i=1}^{Ru} \sum_{j=1}^{Cu} Ec_{lu,lh,i,j} \quad (1)$$

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 CO_2 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.

$$Z2 = Max \sum_{lu=1}^{LU} \sum_{lh=1}^{LH} \sum_{i=1}^{Ru} \sum_{j=1}^{Cu} Car_{lu,lh,i,j} \quad (2)$$

2.2.3 Soil fertility factor function
Third function is minimizing land degradation, so it mean we have to maximizing land fertility, In this function formulation, Z3 was defined as maximizing land fertility factor where $Fer_{lu,lh,i,j}$ 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.

$$Z3 = Max\sum_{lu=1}^{LU}\sum_{lh=1}^{LH}\sum_{i=1}^{Ru}\sum_{j=1}^{Cu} Fer_{lu,lh,i,j} \quad (3)$$

2.3. Non dominatd sorting
Non dominated sorting is one of the multi-objective genetic algorithm process which give 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 populatioin [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 individual are located in same front then choose the bigger value of crowding distance.
- If Individual are located in different rank 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].

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.

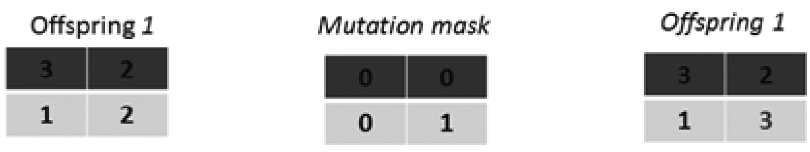

Figure 4. Mutation operator

IOP Conf. Series: Earth and Environmental Science **54** (2017) 012102 doi:10.1088/1755-1315/54/1/012102

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].

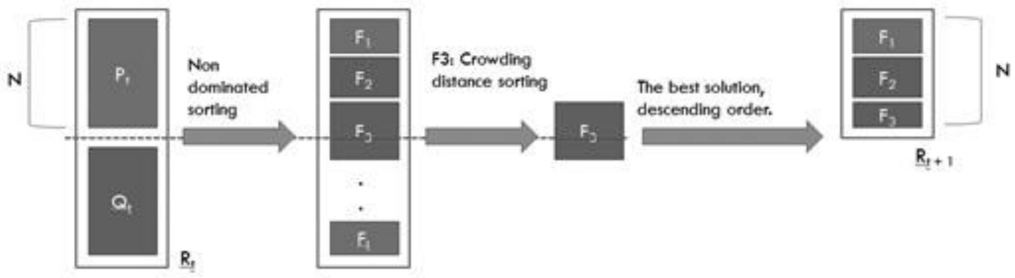

Figure 5. Recombination

3. Results and Disucussions

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.

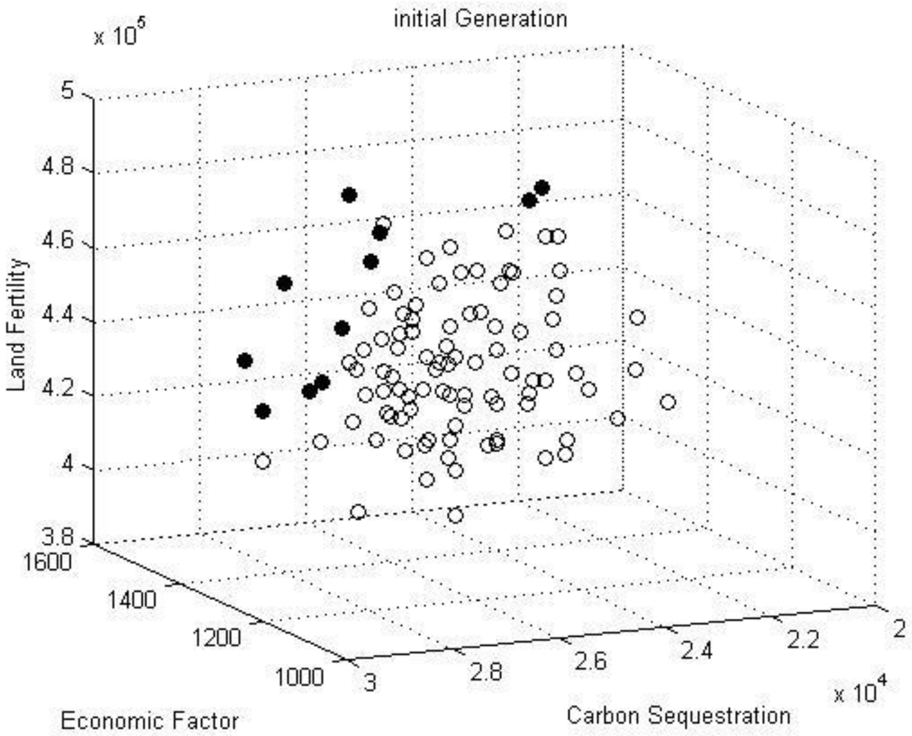

Figure 6. Plot initial population

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.

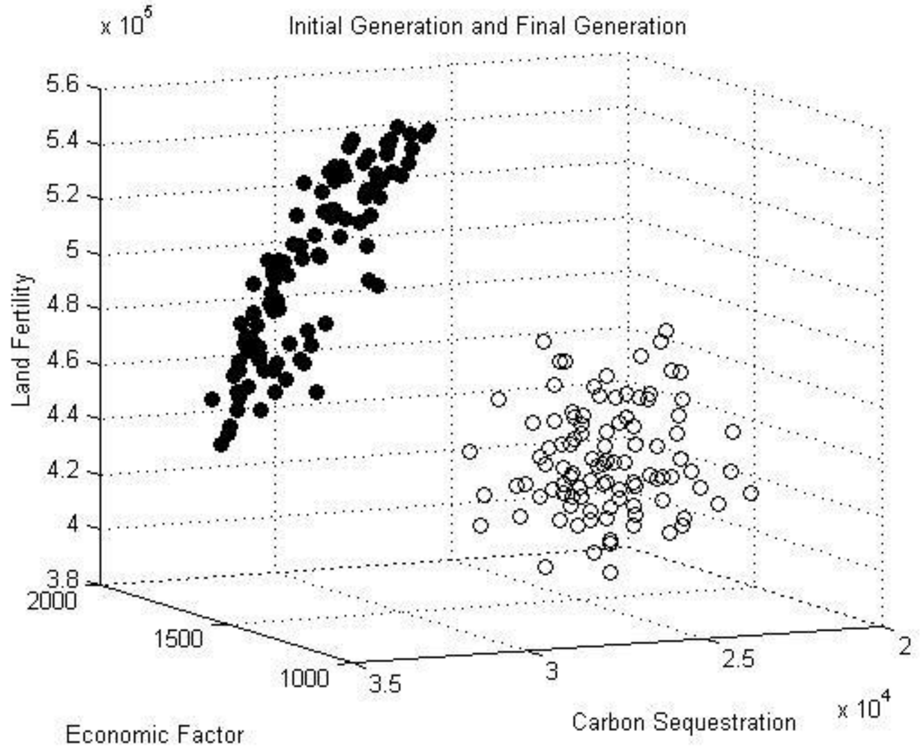

Figure 7. initial and final generation

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

References

[1] Langkvist M, Kiselev A, Alirezaie M and Loutfi A 2016 Classification and segmentation of satellite orthoimagery using convolutional neural network *Remote Sensing* **8**

[2] Arkeman Y, Seminar K B and Gunawan H 2012 *Algoritma genetika Teori dan Aplikasinya untuk Bisnis dan Industri* (Bogor: IPB Press)

[3] Jong K A D 2006 *Evolutionary Computation A Unified Approach* (London: MIT Press)

[4] Bagchi T P 1999 *Multiobjective Scheduling by Genetic Algorithm* (India: Kluwer Academic Publisher)

[5] Arkeman Y, Herdiyeni Y, Hermadi I and Laxmi G F 2013 *Algoritma genetika tujuan jamak (multi-objective genetic algorithms): teori dan aplikasinya untuk bisnis dan agroindustri* (Bogor: IPB Press)

[6] Ratono J, Seminar K B, Arkeman Y and Suroso A I 2015 ERP selection using fuzzy-MOGA approach: A food enterprise case study *TELKOMNIKA* **12**

[7] Zhiyuan H, Piqiang T, Gengqiang P 2005 Multi-objective optimization of cassava-based fuel ethanol used as an alternative automotive fuel in Guangxi, China *ELSEVIER* **83**

[8] Ren Z and Lu X 2011 Using GA for land use planning *IEEE*

[9] Mulyani A and Las I 2008 Potensi sumber daya lahan dan optimalisasi pengembangan komoditas penghasil bioenergi di Indonesia *Jurnal Litbang Pertanian*
[10] Amin M, Hanum C and Charloq 2015 Kandungan hara tanah dan tanaman kelapa sawit menghasilkan terhadap pemberian tandan kosong kelapa sawit dan kedalaman biopori *Jurnal Online Agroekoteknologi*
[11] Astuti E 2008 Pengaruh konsentrasi katalisator dan rasio bahan terhadap kualitas biodiesel dari minyak kelapa *Jurnal Rekayasa Proses*
[12] Zhang H H, Zeng Y N and Bian L 2010 Simulating multi-objective spatial optimization allocation of land use based on the integration of multi-agent system and genetic algorithm *International Journal Environ* **4**
[13] Stewart T J, Janssen R and Herwijenen M V 2004 A genetic algorithm approach to multiobjective land use planning *ELSEVIER* **31**
[14] Datta D, Deb K, Fonsecca C M, Lobo F and Condado P 2007 Multiobjective evolutionary algorithm for land-use management problem *International Journal Computational Intelligence Research* **3**
[15] Shaygan M, Alimohammadi A, Mansourian A, Govara S and Kalami S M 2014 Spatial multi-objective optimization approach for land use allocation using nsga-ii *IEEE*
[16] Cao K, Batty M, Huang B, Liu Y, Yu L and Chen J 2011 Spatial multi-objective land use optimization:extensions to the non-dominated sorting genetic algorithm-II *International Journal of Geographical Information Science* **25**
[17] Firdaus, Arkeman Y, Buono A 2016 A multiobjective genetic algorithm for land use planning for sustainable biodiesel agroindustry *WCCA.AFITA*
[18] Deb K , Pratap A, Agarwal S and Meyarivan T 2002 A fast and elitist multiobjective genetic algorithm: NSGA-II *IEEE* **6**
[19] Hu X B and Paolo E D 2007 An Efficient genetic algorithm with uniform crossover for air traffict control *ELSEVIER*
[20] Hwan I C and Jung H K 2003 Hybrid genetic algorithm for electromagnetic topology optimization *IEEE*
[21] Hyun J, Kim Y H and Ryou H B 2008 Optimal sensor deployment for wireless surveilance sensor networks by a hybrid steady-state genetic algorithm *IEICE*
[22] Deb K 2011 *Multi-objective evolutionari optimisation for product design and manufacturing* (London: Springer)
[23] Engelbrecht A P 2007 *Computational intelligence an introduction* (South Africa: WILEY)
[24] Haupt R L and Haupt S E 2004 *Practical genetic algorithms* (Ner Jersey: WILEY)
[25] Wise M, Hodson E L, Mignone B K, Clarke L, Waldhoff S and Luckow P 2015 An approach to computing marginal land use change carbon intensities for bioenergy in policy applications *ELSEVIER*