Climate change adaptation strategies in the highland by vegetable farmers

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Abstract. The Highland of Magelang Regency has a strategic role as a vegetable production center in Central Java. Farmers in the highlands of Magelang cultivate various types of vegetables. Since highland vegetable farming hugely depends on rainfall as a primary water source, climate change remarkably affects farming. Vegetable farmers often encounter problems due to climate changes in drought and highly intense rainfall, which caused crop damage. Since specific studies on vegetable farmers’ adaptation strategies to cope with climate changes and their economic effects are still limited, this research aimed to study the phenomenon. The observation was performed by interviewing all members (20 farmers) of the Mutiara Organic farmers group in Sumberejo Village, Ngablak Sub-Regency, Magelang Regency, conducting field observation and soil analysis in September-November 2018. The results showed that farmers developed several adaptation strategies to deal with climate change, namely applying multiple cropping systems, developing organic agriculture, growing vegetables under plastic shelters, and expanding a vegetable nursery as an alternative source of income. Farmers cultivated extra crops in the wet season due to abundant water availability. Organic vegetable farming, which began in 2013, from the higher value of the benefit-cost ratio, was more profitable than non-organic farming. Besides, organic farming’s land quality was also better based on organic carbon (C-organic), Nitrogen (N), Cation Exchange Capacity (CEC), and other nutrients. Therefore this study recommended to develop organic vegetable farming on a broader scale and seriously support farmers’ vegetable nursery business, since it was profitable, contributed significant income for farmers, and strategic for vegetable farming industries development.

1. Introduction
Magelang Regency is the primary vegetable production center in Central Java Province. Of the 26 types of vegetables, consecutively 7, 2, 3, and 4 vegetable types are produced in Magelang and lies in the first, second, third, and fourth-largest area and highest production in the province [1]. These vegetables are generally grown in the highlands, including in the Merapi and Merbabu areas [2]. As a cash crop, vegetable farming is a source of income and welfare for farmers [3].

Vegetable farming depends heavily on climatic conditions due to rainfall as a source of water. Therefore climate change has a broad impact, as in other agricultural sectors [4]. Climate change impacted biophysics, genetics, and management of agriculture [5]. Erratic rainfall patterns, the increasing atmosphere temperature, and the early rainy season followed by dry weeks are common natural phenomena due to climate change [6]. In vegetable and fruit crops, climate change reduces the
quantity and quality of production, the emergence of new pests, increased pest and disease attacks, crop failure, decreased irrigation water capacity, and changes in land and crop suitability [7].

By nature, farmers are risk averters [8]. They apply mitigation and adaptation efforts to anticipate climate change impacts [4][9]. It encourages many researchers to study farmers’ decision and intensity of climate change adaptation in several parts, as in Chile [10], China [11], West Africa [12], and Indonesia [6][7]. Servina [7] stated that farmers apply several adaptation strategies, namely the environmentally stress-tolerant varieties, adjusting planting times, using water-efficient irrigation techniques, develop new watering technology, and using screen/plastic houses. This paper aimed to identify Magelang vegetable farmers’ adaptation strategies to anticipate climate change and examine their feasibilities.

2. Research method
The research was conducted in Sumberejo Village, Ngablak Sub-Regency, Magelang Regency, in September-November 2018 at 1250 meter above sea level (m asl). The observation was performed by interviewing all members of the Mutiara Organic Farmer Group (20 people) to find out farmers’ strategies in climate change, field observation and soil analysis. The soil analysis compares the quality of organic and non-organic (conventional) cultivated land. The soil analysis included C-organic, Nitrogen (Kjeldahl method), boron, and the availability of nitrate (NO$_3^-$) as well as ammonium (NH$_4^+$).

Finally, vegetable farming profit was counted [13][14]:

$$\pi = TR - TC$$  \hspace{1cm} (1)

where: $\pi$ = farmers’ income/profits (IDR/ha); $TR$ = total revenue (IDR/ha), and; $TC$ = total cost (IDR/ha).

The economic feasibility of vegetable farming was analyzed using a benefit-cost ratio (B/C) [14]:

$$\frac{B}{C} = \frac{\pi}{TC}$$  \hspace{1cm} (2)

While the benefit of organic farming over non-organic/conventional farming was analyzed using marginal benefit costs ratio [14]:

$$MBCR_i = \frac{\frac{\pi_i}{TC_i} - \frac{\pi_j}{TC_j}}{\frac{\pi_j}{TC_j}}$$  \hspace{1cm} (3)

where: MBCR = Marginal benefit-cost ratio of organic over non-organic/conventional farming; $i$ = organic farming, and; $j$ = non-organic/conventional farming. Criteria: $MBCR = 1$: additional income equal additional costs; $MBCR < 1$: additional income is less than the additional cost, and; $MBCR > 1$: additional income is higher than the additional cost.

3. Results and discussion
3.1. Overview of the research site
Sumberejo Village, Ngablak Sub-Regency, is located in the highlands. The land is dominated by sloping land, relatively thick (> 60 cm) depth of the slump, with good fertility and drainage, making it suitable for vegetable farming activities.

Adequate rainfall (2,250 mm/year) supports agriculture activities. Water shortages rarely happened, even though most areas had no irrigation infrastructure. The general population in highland were farmers, even in relatively narrow land (0.1-0.25 ha). Farmers at least cultivated 23 types of vegetables, namely broccoli, beets, chili, chicory, green mustard, cabbages, celery, lettuce, tomatoes, carrots, potatoes, green curly, parsley, green beans, romaine, spinach, radish, zucchini, Chinese cabbages (pakchoy), coriander, and peas.
### Table 1. General conditions of site research and agricultural land in Sumberejo Village and Ngablak Sub-Regency

| Description          | Sumberejo Village | Ngablak Sub-Regency |
|----------------------|-------------------|---------------------|
| Altitude (m asl)     | 1250              | 1160.3              |
| Land slope (%)       | 30                | 39.7                |
| Topsoil depth (cm)   | 60                | 65.9                |
| pH                   | 6                 | 6.2                 |
| Drainage             | Good              | Good                |
| Soil fertility       | Good              | Good                |

### 3.2. Farmers' adaptation strategies

Vegetable farmers in Magelang Regency developed several adaptation strategies to face climate change were as follows: applying multiple cropping systems, developing organic agriculture, growing vegetables using the plastic shelter, and vegetable nursery as an alternatives source of income. The strategies were as follows.

### Table 2. Opportunities for farmers to grow a particular type of vegetable (%) in wet and the dry season

| Vegetable          | Wet season | Dry season |
|--------------------|------------|------------|
| Broccoli           | 100.0      | 100.0      |
| Chili              | 83.3       | 72.2       |
| Cabbage            | 66.7       | 27.8       |
| Chinese cabbage    | 72.2       | 55.6       |
| Beetroot           | 55.6       | 55.6       |
| Celery             | 55.6       | 44.4       |
| Tomato             | 55.6       | 50.0       |
| Carrot             | 55.6       | 50.0       |
| Pakcoy             | 55.6       | 44.4       |
| Lettuce            | 27.8       | 33.3       |
| Potato             | 22.2       | 16.7       |
| Spinach (Horenso)  | 16.7       | 11.1       |
| mustard greens     | 5.6        | 0.0        |
| Parsley            | 11.1       | 11.1       |
| Bean               | 5.6        | 5.6        |
| Green curly        | 5.6        | 16.7       |
| Radish             | 5.6        | 0.0        |
| Green Romain       | 5.6        | 5.6        |
| Spinach            | 5.6        | 5.6        |
| Zucchini           | 5.6        | 0.0        |
| Coriander          | 5.6        | 0.0        |
| Peas               | 0.0        | 5.6        |
| Others             | 44.4       | 38.9       |

### 3.2.1. Multiple cropping

In line with other studies [11][12], farmers applied multiple cropping to reduce crop failure due to climate change adaptation. Besides, the farmer group asked members to plant a
specific commodity to meet consumers’ demands. The crops cultivated in each season depending on the age of the vegetables, prices, and rainfall.

Farmers in Central-Benin, West Africa, apply multiple cropping systems by growing two or more crops on the same field either simultaneously or one after another [12]. On the other hand, vegetable farmers in Ngablak divided their land into several parts with different crop-combinations. At each area, farmers planted various types of vegetables, ranging from two to four commodities. Among the approximately 23 vegetable types, there were at least 37 and 32 crop-combinations in the rainy and dry seasons.

Vegetable types cultivated in the wet and dry seasons were similar. However, the number of commodities in the dry season was less (Table 2), related to the limited water sources. Farmers did not plant some commodities in the dry season. The three primary commodities planted in the rainy season were broccoli, chili, and Chinese cabbage. In contrast, most farmers plant broccoli, chili, Chinese cabbage, and beetroot in the dry season.

3.2.2. Organic vegetables. Vegetable farmers commonly applied high doses of chemical fertilizers and pesticides. Farmers applied pesticides to anticipate pests and disease attacks. Several factors influenced farmers' perceptions of pesticide use, namely, pest attack risk, the cultivars' resistance to pests, and farmers' knowledge of pesticide impact [15]. Continuous high doses of pesticides will accumulate on products, polluting the environment, reducing productivity, and poisoning humans as well as animals [16].

Farmers' blood tests in Sumberejo Village showed a tendency of health problems [16], supporting the previous results. In July 2007, in Kanigor Village, Ngablak Sub-Regency, Magelang, nine residents are reported dead due to pesticide residues [17].

Such condition encourages young farmers to develop organic vegetables, especially since organic vegetables' price is higher than non-organic. One of them was Mutiara Organic, established in 2013. Organic vegetable demand increases since it is considered healthier than non-organic [18].

Vegetable farming was profitable (Table 3). However, the B/C value of organic farming was higher than conventional. The marginal benefit-cost ratio (MBCR) values were higher than 1, which means additional profits were higher than the additional costs. Organic farming's real profit was even higher since farmers did not pay in cash some of the costs, namely homemade liquid organic fertilizers and laborers.

Although organic farming was more profitable than conventional, farmers could not instantly change their conventional to organic farming. A particular certification body should inspect the land. Besides, there was a transition period from conventional to organic farming. During the period, farmers almost did not get any yield. Farmers benefit in the third year, and the yield gradually increased.

| Item           | Broccoli     | Cabbage     | Mustard greens |
|----------------|--------------|-------------|----------------|
|                | non-organic  | organic     | non-organic    | Organic        |
| I. Costs:      | 2.323        | 2.654       | 1.446          | 1.415          | 1.230          | 2.300          |
| - Seed         | 234          | 250         | 90             | 90             | 70             | 100            |
| - Fertilizers  | 742          | 584         | 216            | 325            | 395            | 550            |
| - Pesticides   | 158          | 584         | 140            | -              | 21             | -              |
| - Labor        | 1.189        | 1.820       | 1.000          | 1.000          | 744            | 1.650          |
| II. Return     | 5.409        | 6.358       | 2.000          | 2.500          | 2.625          | 4.900          |
| III. Benefit   | 3.020        | 3.640       | 554            | 1.085          | 1.395          | 2.600          |
| B/C            | 1.30         | 1.37        | 0.38           | 0.77           | 1.13           | 1.13           |
| MBCR           | 1.87         | 17.13       |                |                |                |                |
Organic farming was considered one of the climate change adaptation efforts [19] since it emits much lower greenhouse gas (GHG) emissions and fastly, affordable and effectively sinks carbon into the soil. Organic farming reduces GHG, mainly because it does not use any chemical fertilizers. Soil analysis showed that the nutrients and quality of land utilized in organic farming were better than non-organic (Table 4). It indicated the positive impact of organic farming on land quality. Previous research reported that organic fertilizers can increase soil fertility, land quality, and soil productivity [20][21]. The application of organic fertilizers able to repair soil characteristics (physical, chemical, and biological), intensify land productivity, narrow the environmental pollution, and prevent land degradation [21][22].

Organic fertilizers are the primary source of soil nitrogen, increasing the C/N ratio. Plants achieve optimal productivity when the C-organic is more than 2.0% [22]. Organic and clay materials are the main components in the formation of aggregates, thereby increasing the soil's porosity and facilitating the absorption of water into the soil, thereby increasing the storage capacity of groundwater [21].

3.2.3. Plastic shelter. During the last few years, some farmers planted vegetables under Ultra Violet (UV) plastic shelter supported by bamboo. Plastic shelters have no walls so that organisms and air can freely enter and exit. However, a plastic shelter can function as part of the greenhouse. Plastic house is part of an effort to lower the negative impact of climate change [7].

Farmers stated that the chances of success in vegetable farming under plastic shelters were higher than without shelters. The percentage success of vegetable farming under plastic shelters was about 81.25-90.0% in the wet season and 70-83.57% in the dry season. Meanwhile, without shelter, it was decreased to 70-86.25% in the wet season and 67.5-76.67 in the dry season (Table 5). Previous reports support the results, in which tomato [23] and shallot [24] under plastic shelter do not suffer from high rain intensity.

Unfortunately, not many farmers built plastic shelters. Only one-third of the Mutiara Organic members used plastic shelters due to their high investment and cost. It cost around IDR 24.4 million (Table 6) per 500 square meters. Plastic shelters also required maintenance of as much as IDR 467 thousand a year. Farmers stated that plastic shelter had a shelf life of about 4.08 years.

| Table 4. Soil analysis on the organic and non-organic vegetable in Sumberejo Village, Ngablak Sub-Regency, Magelang Regency |
|--------------------------------------------------|
| **Organic soil depth (cm)** | **Non-organic soil depth (cm)** |
|-------------------------------|-------------------------------|
| C-organic (%)                 |                               |
| 0-20                          | 20-40                         |
| 3.72                          | 3.33                          |
| 2.55                          | 2.55                          |
| N-Kjeldahl (%)                |                               |
| 0.49                          | 0.42                          |
| 0.36                          | 0.36                          |
| CEC cmol (+) kg-1             |                               |
| 32.61                         | 34.69                         |
| 23.89                         | 37.05                         |
| Total nutrients:              |                               |
| Boron (ppm)                   |                               |
| 34.20                         | 55.92                         |
| 50.67                         | 62.34                         |
| Available nutrients:          |                               |
| Boron (ppm)                   |                               |
| 0.87                          | 0.78                          |
| 0.46                          | 0.47                          |
| NO₃ available (ppm)           |                               |
| 45.27                         | 45.66                         |
| 27.92                         | 26.57                         |
| NH₄ available (ppm)           |                               |
| 17.57                         | 6.00                          |
| 5.86                          | 5.04                          |
It encouraged vegetable seed cultivate reaching an average of 13%. The value is much lower than the contribution of farmers' income from vegetables. Some vegetable farmers also produce ready plant seeds. Farmers commonly avoid risks by using certified seeds for higher productivity [8] and stress-tolerant varieties [7]. The availability of qualified vegetable seeds is crucial [3]. As in other places [25], it encouraged vegetable seed and nursery industries growth in Ngablak. In the vegetable nursery, farmers sowed the seeds, care for, and sell the ready-to-plant seedling to farmers. Some vegetable farmers also produce ready-to-plant seeds. Farmers did the business to diversify their income source, especially in the drought incidences when no harvest vegetables.

The contribution of the ready-to-plant vegetable seeds to household income was quite significant, reaching an average of 13%. The value is much lower than the contribution of farmers' income from vegetable seed producers (cucumber, chili, and eggplant) in Karang Sidemen Village, North Batukliang Sub-Regency, Central Lombok Regency, which reaches 84.9% in the six months [26].

Farmers marketed the seeds inside and outside the district, and even outside the province. Farmers cultivated various types of ready-to-plant seeds. Some of them were broccoli, chicory, chili, tomato, and

3.2.4. Vegetable nursery as an alternative source of income. Farmers commonly avoid risks by using certified seeds for higher productivity [8] and stress-tolerant varieties [7]. The availability of qualified vegetable seeds is crucial [3]. As in other places [25], it encouraged vegetable seed and nursery industries growth in Ngablak. In the vegetable nursery, farmers sowed the seeds, care for, and sell the ready-to-plant seedling to farmers. Some vegetable farmers also produce ready-to-plant seeds. Farmers did the business to diversify their income source, especially in the drought incidences when no harvest vegetables.

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### Table 5. The chance of success (%) of vegetables planted by season in Sumberejo Village, Ngablak Sub-Regency, Magelang Regency

| Commodity      | Without plastic shelter | Under plastic shelter |
|----------------|--------------------------|------------------------|
|                | Wet season | Dry season | Wet season | Dry season |
| Broccoli       | 80.88±2.26 | 74.58±4.16 | 88.50±2.09 | 80.00±6.42 |
| Celery         | 77.73±3.82 | 70.68±5.45 | 86.43±4.64 | 73.00±7.33 |
| Carrots        | 86.25±2.99 | 69.04±4.28 | 90.00±5.06 | 68.00±6.65 |
| Beets          | 83.18±4.99 | 74.38±5.47 | 89.72±4.65 | 83.57±8.74 |
| Chicory        | 79.38±3.68 | 70.31±5.55 | 85.94±5.07 | 75.71±9.43 |
| green mustard  | 80.42±4.74 | 72.12±6.37 | 89.50±3.08 | 79.29±12.18 |
| Chilli         | 79.64±4.53 | 68.04±4.93 | 82.50±4.90 | 75.71±8.12 |
| Tomatoes       | 75.91±5.88 | 69.00±5.23 | 81.25±8.92 | 66.67±8.64 |
| Horenso        | 70.00±19.60 | 66.67±3.27 | 85.00±0.00 | 70.00±0.00 |
| Tatsoi pagoda  | 60.00±0.00 | 60.00±0.00 | 80.00±0.00 | 70.00±0.00 |
| Cabbages       | 70.00±0.00 | 70.00±0.00 | 90.00±0.00 | 80.00±0.00 |
| Potatoes       | 80.00±0.00 | 60.00±19.60 | - | - |
| Romaine        | 80.00±0.00 | 70.00±0.00 | - | - |
| coriander      | 80.00±0.00 | 70.00±0.00 | - | - |
| Kale           | 90.00±0.00 | 70.00±0.00 | - | - |
| Parsley        | 90.00±0.00 | 70.00±0.00 | - | - |

### Table 6. Investment costs of plastic shelters for vegetable farming in Sumberejo Village, Ngablak Sub-Regency, Magelang Regency

| Items           | Volume (unit) | Price per unit (IDR) | Amount (IDR) |
|-----------------|---------------|----------------------|--------------|
| Material costs  |               |                      |              |
| - Bamboo        | 311.67 Trees  | 20,833.33            | 6,493,056    |
| - nails         | 8.83 Kilograms | 15,000.00            | 132,500      |
| - Wire / string | 14.17 Kilograms | 53,000.00            | 750,833      |
| - UV Plastic    | 354.17 Meters | 22,083.33            | 7,821,181    |
| - Screen        | 10.00 Roller  | 268,750.00           | 2,687,500    |
| Labor           | 1.00 Package  | 6,503,000.00         | 6,503,000    |
| Total costs     |               |                      | 24,388,069   |
cabbage. The production capacity of seeds in the rainy season was much higher than in the dry season because most of the consumers come from dry land/non-irrigated land areas, which highly depends on the season.

**Table 7.** Description of vegetable nursery business in Sumberejo Village, Ngablak Sub District, Magelang District

| Commodities       | Production periods (times/season) | Production capacity (seeds/period) | Seed price (IDR/plant) | Share/season (x 1000 IDR) |
|-------------------|-----------------------------------|-----------------------------------|------------------------|---------------------------|
|                   | Wet season | Dry season | Wet season | Dry season | Wet season | Dry season | Wet season | Dry season |
| Broccoli          | 5.67       | 4.67       | 45,667     | 24,556      | 150        | 150        | 9,250      | 4,283       |
| Chinese cabbage   | 7.00       | 7.00       | 60,714     | 32,143      | 150        | 150        | 6,071      | 3,214       |
| Cayenne pepper    | 3.33       | 4.00       | 45,000     | 31,250      | 150        | 150        | 6,071      | 3,214       |
| Curly Red Chili   | 3.00       | -          | 6,000      | -           | 150        | -          | 4,500      | -           |
| Tomato            | 5.67       | 4.33       | 40,222     | 14,556      | 150        | 150        | 9,111      | 2,911       |
| Cabbage           | 4.00       | 4.00       | 50,000     | 55,000      | 150        | 150        | 5,000      | 5,500       |

**Table 8.** Financial analysis of broccoli and cabbage nursery (per 100 m² of plastic shelter) in Sumberejo Village, Ngablak Sub-Regency, Magelang Regency

| Items                        | Broccoli | Cabbage |
|------------------------------|----------|---------|
| Production capacity per period | 100,000 | 190,000 |
| Cost (IDR)                   | 3,721,025| 6,313,025|
| – Input costs                | 2,193,000| 4,685,000|
| – labor                      | 900,000  | 1,000,000|
| – Depreciation               | 628,025  | 628,025  |
| Return (IDR)                 | 13,500,000| 19,000,000|
| Benefit (IDR)                | 9,778,975| 12,686,975|
| B/C                          | 2.63     | 2.01    |
4. Conclusion
Vegetable farmers applied four adaptation strategies to cope with climate change, namely multiple cropping, organic farming, plastic shelter using, and developing vegetable nursery for income diversification. Multiple cropping with organic farming was more profitable than non-organic vegetable farming. Soil analysis results also showed that organic farming's land quality was higher (C-organic, N, CEC, and available nutrients) than those managed conventionally.

Planting vegetables under plastic shade was also prospective as an adjustment to climate change. The chances of the success of farming vegetables grown under plastic shelter were higher than without shading. To reduce uncertainty income from vegetable farming due to climate change, farmers developed a vegetable nursery business. Aside from supporting vegetable farming in the region, the profitable business contributed enough income to farmers highly.

The research recommended developing broader scale organic vegetable farming. Besides producing healthier products, organic vegetables did not harm farmers and their families' health and ensure food production sustainability in the future. It also recommended supporting the development of farmers' vegetable seed industries. Farmers needed to be equipped with knowledge about healthy nursery technology to prevent the spread of seed-borne disease and the use of certified seeds. This research was a case study. Therefore, more research is needed to obtain in-depth and broader information on farmers’ perceptions and adaptation efforts to cope with climate change, which involves more respondents from several vegetable production centers.

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