Assessing Indonesian sugarcane farmers' perceptions of climate change

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Abstract. Climate change is expected to have severe economic, social and environmental impacts on Indonesia. Here we focus particularly on sugarcane farmers in West Java. Analysis of historical climate data shows a downward trend in annual rainfall in the last 20 years. The rainfall pattern in this area is monsoonal with a peak from December to January and a dry season from June to September. Future climate scenarios indicate that precipitation will decrease particularly from November to December, which coincides with the planting time for a new cane crop. Increased probability of drought at this time has been identified as the significant climate change impact on sugarcane farmers. The temperature is predicted to increase but will remain within the crop tolerance range, therefore is not expected to be a significant issue. This research seeks to gain insights from the farmers themselves on their adaptation responses based on questionnaires. Data were collected from 210 individual respondents in Cirebon Regency. The study examines how farmers perceptions correspond with the climate record. The farmers' perceptions of climate change are in line with data records. The factors that influence farmers perceptions were analysed by an econometric approach using binary logistic regression. The results showed that farmers perception of climate change was significantly related to education, farming experience, effort to irrigate, sugarcane variety, and the age of crops. We are sceptical about the reality of these perceptions. In reality, it is very unlikely that anybody can perceive the average temperature changes less than 1 degree over 38 years.

1. Introduction

Indonesia is located between 6°08' North and 11°5' South latitude, and from 94°45' to 141°05' East longitude. The country covers 1,910,931 km². Cirebon is in the eastern part of West Java and is a boundary as well as a gateway, to Central Java. The area is situated at a latitude of 6°30’ to 7°00’ S and 108°40’ to 108°48’ with an area of 990.36 km². The northern part of Cirebon is a low-lying area bordering the Java Sea. In contrast, the southern part is a relatively hilly area, with a maximum height of 500 m above sea level [14].

Indonesia is particularly vulnerable to the effects of climate variability and climate change because of its geographical place, topography and socio-economic dimensions [8]. Based on the analysis of
Global Circulation Model (GCM) output, the projected average temperature increase in Indonesia is between 0.8 – 1°C from 2020 to 2050, relative to the baseline period of 1961 – 1990. The temperature increases for Java region for 2070 – 2100, relatively to the period of 1961 – 1990, is projected to reach 2°C, 2.5°C, and 3°C for B1, A1B, and A2 scenarios respectively [11]. These scenarios were the three scenarios of SRES (Special Report of Emissions Scenarios) with the B1 scenario as the lowest emission, A1B as the moderate emission, and A2 as the highest emission of CO₂ concentration level.

The cropping system to produce sugarcane in Java has gradually shifted from wetlands to rainfed cultivated land, allowing wetlands to be prioritised for food crops such as rice, corn, and soybeans [15]. Sugar cane crops differ from many others when it comes to cultivation because sugar cane's commercial product is not derived from the reproductive section of the crop (for example from grain cereals) but the vegetative structures (the cane stalk). Sugarcane is one of the strategic commodities in Indonesia, particularly in Java. The sugarcane-based industry is labour intensive, has broad linkages with the regional and national economic development, and uses agricultural products as inputs. Sugarcane production is vulnerable to climate change through the direct effects of climate-changing conditions, such as changes in temperature and precipitation, as well as through the indirect effects, such as pest and diseases.

Empirical evidence from other sugarcane-producing regions shows that climate change may pose a risk to sugarcane production. Chandiposha [5] has examined the potential adverse effects on Zimbabwean sugar cane production of climate change, especially temperatures and rainfalls. Gawander [7] reported that sugarcane and sugar yields in Fiji have fluctuated with extreme climate events (drought and tropical cyclones). A record sugar production (516,529 tonnes) in Fiji in 1994 was recorded because of favourable weather, on the other hand, sugar productions in 1997, 1998, and 2003 were 47, 50, and 43%, respectively, lower than that in 1994 due to drought conditions.

Climate change prediction model suggests a shift in precipitation patterns. The model for future climate scenario on the study area is GCMs (Global Climate Models) using CMIP5 (Coupled Model Intercomparison Project Phase 5) with scenario RCP2.6, RCP 4.5, RCP 6 and RCP8.5. The model name is CSIRO-Mk3-6-0 developed by the Commonwealth Scientific and Industrial Research Organization, Australia [12]. This model indicates that precipitation will decrease particularly in November – December, which coincides with the planting time for a new cane crop. Any decrease in the amount of water available to sugar cane may cause water stress, conditions that negatively impact physiological processes including photosynthesis, stomatal conduct and breathing. Modification of the physiological cycle is expected to reduce crop growth and the yield of sugarcane [6].

Previous studies conducted by Abid et al. [1], Allahyari et al. [2], Carrera et al. [4], Lasco et al. [9], Li et al. [10], and Yamauchi et al. [13] show that the awareness of climate change is widespread throughout many countries. Farmers’ decision to adapt to climate change is influenced by a range of internal and external factors. Empirical research on climate change adaptation illustrates that decision to innovate or adapt, is primarily determined by perceptions of knowledge, risk, goals, and experience [1,2,4,10]. The farmers’ perception influences their motivation or intention to act, an essential factor in decision making related to climate change adaptation [1,2,9,13]. Abid et al. [1] described the farmers’ adaptation process as a three-step procedure, perception – intention – adaptation.

This study mainly seeks to answer a key research question: how do sugarcane farmers perceive changes to the local climate? Furthermore, this study also considers the factors affecting sugarcane farmers’ perception in the study area. The study employs a binary logistic model to determine the factors affecting farmers’ perception.

2. Materials and Methods

2.1. Sampling and data collection
Primary data for this paper was collected by a structured questionnaire. The study was conducted in Cirebon Regency, West Java Province, Indonesia. Sugarcane in West Java is produced by smallholder farmers and a sugar state-enterprise, PT RNI 2. Currently, PG RNI2 have four active sugar mills in
West Java. Two of them, are located in Cirebon Regency, namely, PG Sindang Laut and PG Tersana Baru. The study focused on the smallholder farmers in both sugar mills area that supplying sugarcane for sugar mills.

The survey was conducted in from July to August 2018. For the data collection, 210 farmers were interviewed. A structured questionnaire was used to gather information on socio-economic characteristics, sugarcane farming system, land tenure, access to input, access to various services, current and past farming practice, perceive to climate changes and climate variability, and current adaptation practice.

The survey used stratified sampling. The first stratification was by zones, Sindang Laut zone, and Tersana Baru zone. The second stratification was by farmer annual sugarcane production. The underlying population of farmers used in this survey was obtained from both sugar mills. Each list of farmers’ names was divided into four categories based on their sugarcane production. Farmers’ names within each category were sorted alphabetically and numbered. Then from these lists, a name was selected sequentially every 3 or 4 entries. We selected five additional farmers in each category as reserves, to be used, to replace any farmer who had been selected but who could not subsequently be interviewed.

2.2. Dependent and independent variables
To analyse the determinants affecting perception to climate change of sugarcane farmers, we set up the model as follows:

\[
y_i^* = x_i \beta + \epsilon_i
\]

where \(y_i^*\) is the latent variable indicating whether or not a sugarcane farmer perceives climate change, \(x_i\) denotes the set explanatory variables indicating the factors which affect perception to climate change, and \(\epsilon_i\) is the error term for this equation.

This study used the logit model to analyse the independent variables that affect farmers’ perception. The details of the dependent and independent variables are presented in Table 1. The dependent variable for this study is binary, indicating whether a sugarcane farmer perceives climate change.

| Table 1. Description of models’ variables. |
|-------------------------------------------|
| **Dependent variables**                  |
| **Description**                          |
| **Value**                                |
| Perception of temperature                |
| Farmers’ perception of temperature change|
| 0: not perceiving increasing temperature  |
| 1: perceiving increasing temperature      |
| Perception of the onset of the rainy season|
| Farmers’ perception of shifting of onset  |
| 0: not perceiving later onset of the rainy season |
| 1: perceiving later onset of the rainy season |
| **Independent variables**                |
| **Age of respondent**                    |
| Age of respondent                        |
| 1: less than 30 years                    |
| 2: 30 to 40 years                        |
| 3: 40 to 50 years                        |
| 4: 50 to 60 years                        |
| 5: more than 60 years                    |
| Gender of the respondent                  |
| Gender of the respondent                  |
| 0: female                                |
| 1: male                                  |
| Description                        | Value                                                                 |
|-----------------------------------|-----------------------------------------------------------------------|
| Education of respondent           | Respondents' level of education                                       |
|                                   | 1: primary                                                            |
|                                   | 2: secondary                                                          |
|                                   | 3: high School                                                        |
|                                   | 4: university/college                                                 |
| Farming Experience                | Respondents' farming experience                                       |
|                                   | 1: less than five years                                               |
|                                   | 2: 5 to 10 years                                                     |
|                                   | 3: 10 to 15 years                                                    |
|                                   | 4: 15 to 20 years                                                    |
|                                   | 5: more than 20 years                                                |
| Use of irrigation                 | Farmers that use an irrigation                                       |
|                                   | 0: no, only using rainfall                                           |
|                                   | 1: yes                                                                |
| Access to extension               | Respondent's access to extension officer                             |
|                                   | 0: no                                                                 |
|                                   | 1: yes                                                                |
| Use of credit                     | Farmers that use credit                                               |
|                                   | 0: no                                                                 |
|                                   | 1: yes                                                                |
| Farm size                         | The amount of sugarcane farming                                       |
|                                   | 1: less than 5 ha                                                    |
|                                   | 2: 5 ha to 10 ha                                                     |
|                                   | 3: 10 ha to 15 years                                                 |
|                                   | 4: 15 ha to 20 ha                                                    |
|                                   | 5: more than 20 ha                                                   |
| Owned land                        | farming on the owned land                                            |
|                                   | 0: not only farming on the owned land                                |
|                                   | 1: only farming on the owned land                                    |
| Rented land                       | farming on the rented land                                            |
|                                   | 0: not only farming on the rented land                               |
|                                   | 1: only farming on the rented land                                   |
| Partnership with sugar mills      | Partnership agreement with sugar mill at the beginning of planting time |
|                                   | 0: no partnership                                                    |
|                                   | 1: in-partnership with the sugar mill                                |
| Land type: irrigated              | Type of land for sugarcane farming                                   |
|                                   | 0: not farming on irrigated land                                     |
|                                   | 1: farming on irrigated land                                         |
| Land type: rainfed                | Type of land for sugarcane farming                                   |
|                                   | 0: not farming on rainfed land                                       |
|                                   | 1: farming on rainfed land                                           |
| Main-job                          | The main job of the respondent                                       |
|                                   | 0: not sugarcane farmers                                             |
|                                   | 1: sugarcane farmers                                                 |
| Crop year                         | The type of crop-based on their planting year                         |
|                                   | 1: first-year crop                                                   |
|                                   | 2: second-year crop                                                  |
|                                   | 3: third-year crop                                                   |
|                                   | 4: fourth-year crop                                                  |
|                                   | 5: more than fourth-year crop                                        |

### 3. Results and Discussion
The authors analyzed how climatic data from meteorological stations evolved and how farmers interpreted these changes to assess farmers’ perception of climate change and variability. The test was
undertaken for a linear trend in annual means of temperature, and the onset of the rainy season at Cirebon. Descriptive statistics based on summary counts of the questionnaire were used to provide insight into farmers' perceptions of climate change.

3.1. Temperature changes
About 86 percent of the farmers interviewed perceived long-term temperature changes; decreased or increased. Most of them (82.5 percent or 165 farmers) perceived the temperature in Cirebon Regency to be increasing. Only 3 percent noticed the contrary, a decrease in temperature.

The statistical record of temperature data from Cirebon Regency between 1980 and 2017 shows an increasing trend. In 38 years, the annual average temperature has risen around 0.7 degree Celsius (Fig. 1). Therefore, farmers' perception appears to be following the record in the region. The increase is a statistically significant trend at 5% level; however, in reality, it is very unlikely that anybody can perceive the average temperature changes less than 1 degree over 38 years.

![Figure 1. Perception of temperature changes and trend of the annual average temperature for Cirebon (1980 – 2017) (source: Cirebon meteorological service).](image)

The farmers' perception variable was changed to a dummy variable, as presented in Table 2. The false variable was created by adding up respondent who choose answer decreased and no change. This dummy variable was used as the dependent variable to analyse factors affecting farmers' perception of increasing temperature using the logistic model.

| Frequency | Percent | Valid Percent | Cumulative Percent |
|-----------|---------|---------------|--------------------|
| Valid     |         |               |                    |
| False     | 35      | 17.5          | 17.5               |
| Increased | 165     | 82.5          | 100.0              |
| Total     | 200     | 100.0         | 100.0              |

The result of the logistic model is presented in Table 3. The binary logistic regression analysis was conducted to assess factors influencing farmers' perception of temperature change. The results indicate that farming on irrigated land, in partnership with a sugar mill, who owns the land, the age of farmer, farmers' main job and their crop year influenced the likelihood that a farmer can correctly perceive temperature changes.

Farmers on irrigated land were more likely to perceive that temperature has increased. Farmers on irrigated land were relatively wealthier than farmers on rainfed land. Therefore, they might more be correctly informed than other farmers.
Table 3. Logistic model result of determinant variables of farmers’ perception of temperature changes.

| Model | Farming on irrigated land | B    | Std Error | Sig.  |
|-------|---------------------------|------|-----------|-------|
|       | Partnership with sugarmill| 1.422| 0.645     | 0.027 |
|       | Owned land only           | 1.761| 0.606     | 0.004 |
|       | Age of farmer             | -0.363| 0.207    | 0.079 |
|       | Main_job                  | 1.406| 0.518     | 0.007 |
|       | Crop_year                 | 0.350| 0.175     | 0.045 |
|       | Constant                  | -0.832| 0.950    | 0.381 |

Note: This model predicted 74.5% of observation correctly.

In terms of land ownership, farmers who own their farmland have a positive value and significant effect in the model. These conditions suggest that land tenure affects the farmers' perception. Farmers that have a partnership with the sugar mill and recently planting new sugarcane crop were more likely to perceive that the temperature has increased. The variable that represents the age of farmers was not significant at the 5% level and had a negative value. The negative value indicates that younger farmers were more likely to have correctly perceived increasing temperature. This condition possibly affected by their education and the ability to access different information compared with older farmers.

The variable that represents the main job of farmers was significant and had a positive value. The positive value indicates that farmers that only farm sugarcane as their primary job is more likely to have a perception about increasing temperature.

3.2. Shifting rainy season
Almost 87 percent (or 173 respondents) noticed a change in the timing of the rainy season, with the rainy season coming either earlier or later than expected. Seventy-two percent of respondents (143 respondents) noticed rains coming later than expected.

The Indonesian National Meteorological Service (BMKG) define the onset of the wet season as the first day, after 1 September, of three consecutive 10-day periods with cumulative precipitation higher than 50 mm in each of the 10-day periods. The end of the wet season is defined similarly, but now regarding three consecutive 10-day periods with accumulated precipitation less than 50 mm (BMKG, 2014).

![Figure 2](image-url). Farmers’ perception of the onset of the rainy season and the onset of the rainy season in the study area.
Figure 2 shows the onset of the rainy season using the Indonesian BMKG definition. The beginning of the rainy season in the study area has very high variability. Seasonal monsoon is a dominant climate feature that affects agriculture in this region. Farmers’ perception that the onset of the rainy season is shifting agrees with the study area data. However, there is no statistically significant trend in the onset of the rainy season data on 5% level.

The farmers' perception variable of the onset of the rainy season was changed to a dummy variable, as presented in Table 4. "Perceived the onset of the rainy season is change" variable was created by adding up respondents that choose answer earlier and later. This dummy variable was used as the dependent variable to analyse factors affecting farmers’ perception of the onset of the rainy season.

Table 4. Dummy of farmers’ perception of the onset of the rainy season.

|                                | Frequency | Percent | Valid Percent | Cumulative Percent |
|--------------------------------|-----------|---------|---------------|--------------------|
| Valid Perceived the onset of the rainy season is change (0) | 173       | 86.5    | 86.5          | 86.5               |
| Perceived the onset of the rainy season is not change (1)   | 27        | 13.5    | 13.5          | 100.0              |
| Total                                                        | 200       | 100.0   | 100.0         |                    |

The binary logistic regression analysis was conducted to assess factors influencing farmers’ perception of the onset of the rainy season. The results indicated that use of irrigation, farming experience, and crop_year influenced the likelihood that a farmer correctly perceives the onset changes.

Table 5. Logistic model result of determinant variables of farmers’ perception of shifting of the onset of the rainy season.

|                                | B      | S.E.   | Sig.   |
|--------------------------------|--------|--------|--------|
| Model 2 Use of irrigation      | -1.535 | 0.814  | 0.059  |
| Farming experience             | 0.436  | 0.169  | 0.010  |
| Crop_year                      | 0.296  | 0.180  | 0.099  |
| Constant                       | -3.777 | 0.874  | 0.000  |

Note: This model predicted 83 % of observation correctly

Farmers that were not irrigating their sugarcane crop were more likely to perceive the onset of the rainy season correctly. This condition indicates that farmers’ perception about the later onset of the rainy season was related to their effort to irrigate sugarcane crop. They use more irrigation recently due to shifting to rainfed land and El Nino effect in 2015, and this affected their perception on the onset of the rainy season.

Interestingly, most of the farmers (86.5% or 173 farmers) perceived that the onset of the rainy season was later or earlier. This perception was correct in the short period (last 7 years), however in the long run (38 years) this perception was not correct. This perception might be affected by farmers’ short term experience. The model 2 suggests that more experienced farmers were more likely to perceive the onset of the rainy season correctly -that there was no change in the onset of the rainy season-. Less experienced farmers might perceive the onset of the rainy season differently from more experienced farmers.

The farmers that were not recently planting sugarcane crop were more likely to perceive the onset of the rainy season correctly. The onset of the rainy season is greatly affecting the first crop of sugarcane. Therefore, farmers that have ratoon crops might be not aware or no interest in the change of the onset of the rainy season. The change of the onset of the rainy season was not affecting their crop.
4. Conclusions
Farmers' perception of increasing temperature and shifting of the onset of the rainy season was analysed quantitatively. On the temperature, in 38 years the temperature increases by 0.7 degrees Celcius is a statistically significant trend. However, in reality, is extremely problematic perceiving temperature changes less than 1 degrees over 38 years. The results of this logistic analysis indicated that farming on irrigated land, partnership with a sugar mill, owned land only, age of farmer, farmers' main job and their crop_year influenced the likelihood that a farmer can correctly perceive temperature changes.

On the shifting of the rainy season, farmers' perception that the onset of the rainy season is shifting not agrees with the study area data. The results of binary logistic regression analysis indicated that farmers' experience, use of irrigation, and crop_year influenced the likelihood that a farmer correctly perceives the onset changes.

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