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Deriving vulnerability indicators for crop production regions in Indonesia

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Abstract. Food supply is considered as one of the most vulnerable to the effects of climate change. Higher temperature and changes in rainfall patterns and intensity may adversely impact crop production, which will eventually affect the food supply. Consequently, adaptation strategies should be devised to minimize the potential adverse impacts and maximize its potential benefits. The adaptation strategies should be devised by considering factors contributed to causing vulnerability following the concept of food supply chain, starting from production to consumption. This study focuses on identifying the contributed factors to vulnerability of crop production regions in Indonesia. The contributed factors were identified by defining indicators for each component of the food supply chain using an example of crop production centers in Indonesia, the West Java Province. The identification considers existing issues of the food supply chain, covering aspects of production, post-harvest and storage, distribution, and consumption, based on the field surveys conducted in Indramayu district of the West Java, the main grower of paddy production, and Garut district of the West Java, the main grower of corn production. The selection of the vulnerability indicators was also considered the data availability for the study area. The analysis proposed a list of indicators classified into production, post-harvest and storage, distribution and consumption that are proposed to assess the regional vulnerability of crop production regions in Indonesia. This result is expected to contribute in understanding the process of devising climate change adaptation intended for enhancing food supply resilience to climate change.

1. Introduction

Food supply chain is a complex process, composing of several steps starting from production, post-harvest dan storage, distribution, and consumption. Many factors control each step of the supply chain, which can be generally categorized into biophysical factors (e.g., climate, land) and socio-economic condition (e.g., access to seeds, fertilizers, machinery, farming technology, farmers' network, storage system, transportation, and etc). Climate fluctuation has been widely acknowledged affecting crop productivity over a crop growing region, assuming the land fertility is maintained. This climate sensitivity has drawn attention worldwide in anticipating the potential impacts of climate change on crop production [1-3], which can eventually affect the food supply. The socio-economic condition



contributes to create enabling condition, namely: the farming activities (i.e., the production process), the access to crop production, and the consumption to the food supply.

As an agricultural country, Indonesian government is already paid a serious attention to stabilize food supply, particularly staple food (i.e., rice), in meeting the domestic demand for food. Two major challenges associated with the crop production process are climate extremes and agricultural land conversion. Climate extremes, which may be exacerbated by the global climate change, can hamper crop growth and development [4, 5], resulting in declining farm production [6, 7]. Climate extremes, leading to climate hazards (e.g., droughts and floods), have been reported posing serious challenges in crop production over central growing areas in Indonesia, such as West Java Province, one of the national production centers of food crops (i.e., paddy and corn). The province contributes about 15% and 4.9% for the national rice and corn production, respectively [8]. Two main crop growing areas in the West Java are the Indramayu district for paddy (about 14.3% of the provincial paddy production) and the Garut district for corn (about 59.2% of the provincial corn production) [8]. Climate extremes associated with drought caused paddy production failure of about 16 thousand hectares and paddy production damage called ‘puso’ of about a thousand hectare in Indramayu [8, 9]. In addition, drought occurred in the district of Garut reported on 25/9/2012 damaged thousand hectares of corn production (‘puso’) such as those occurred in the sub-district of Banyuwangi [10].

Concerning the impacts, it is important to learn factors caused the impacts. Theoretically, the potential impacts may be different spatially with regard to the level of regional vulnerability, which is defined as “*the propensity or predisposition to be adversely affected, encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt*” [11]. At the national level, Kementerian Lingkungan dan Kehutanan (Ministry of Environment and Forestry) already launched a tool called Sistem Informasi Data Indeks Kerentanan (SIDIK) (System Information on Vulnerability) in 2015 [12]. This tool is currently purposed to measure the level of regional vulnerability based on the components of risk indicators [11, 10], calculated using available socio-economic data. Thus, further development can be proposed to expand the capability of the SIDIK. This research is proposed to develop vulnerability indicators specifically for food security derived based on the concept of supply chain.

The district of Indramayu and Garut are chosen as the case study. This case was employed particularly to explore contributed factors (i.e., indicators) to measure the vulnerability level that should be considered at each stage of the supply chain (i.e., production, post harvest and storage, distribution, and consumption). The exploration was performed through literature review and stakeholders’ engagement, i.e., discussions and meetings with key players of the supply chain in the two crop production centers. The derived indicators can provide inputs to improve the SIDIK to measure the vulnerability of agriculture sector. The indicators can also provide valuable information on what strategies should be devised, concerning the contributed factors to the regional vulnerability. In the context of climate change, the anticipated strategies are called as adaptation strategies directed to minimize the potential negative impacts of climate change and to maximize its positive impacts [11].

2. Related works

The development of vulnerability indicators for agriculture sector in Indonesia is not really new; although, the indicators derived based on the concept of food supply chain is still rare. As an example, there is on-going works on the development of vulnerability indicators for complex areas called as Agropolitan in Malang. This work aims at developing vulnerability indicators for the components of Agropolitan, namely: agriculture, economy, industry, and tourism [13]. Another study [14] analyzed the factors affected corn production in Garut, identifying land area and seeds significantly controlled corn production. Current work conducted by research and development division of Ministry of Agriculture developed vulnerability indicators in accordance with the definition of food security of the FAO (1996) and Law No. 7 in 1996. The food security defined criteria that should be fulfilled, namely 1) availability; 2) supply stability; 3) accessibility/ affordability, and 4) quality/safety [15].

3. Methodology

Concerning the focus of this research on crop production center, spatial variability of crop production areas in the study region (i.e., West Java) were evaluated. Information on paddy and corn production obtained from the National Statistical Agency were mapped using spatial tools to provide information on crop growing center in the study region. For the selected production centers (i.e., Indramayu for paddy and Garut for corn), spatial variability of productivity and harvested area for paddy and corn was also evaluated to identify major crop growing areas in the centers. This information in accordance with climate classification over the region provides information on which climate type is suitable for crop growing areas. The climate classification was completed using climate classification techniques (i.e., Koppen, Oldeman, and Schmidt – Ferguson) applied to climatological gridded rainfall data of WorldClim 1971-2000 [13, 16]. The development of the vulnerability indicators were completed based on the concept of supply chain and the vulnerability components (i.e., “Sensitivity” and “Capacity”) and the other risk component namely “Exposure” proposed in the IPCC report [11]. The concept of supply chain has been applied to identify factors and its associated issues within each stage of the supply chain, i.e., production, post-harvest and storage, distribution, and consumption, under the exposure of climate change [17]. Field survey was conducted at the two crop growing areas (Indramayu and Garut) to interview key players of each stage of the supply chain. The interview was conducted through meetings or group discussions to explore factors and issues within each stage of the supply chain. This field survey provided information on what indicators should be derived to measure the vulnerability of crop production centers. We grouped the indicators contributed to each stage of the supply chain into the vulnerability components (“Sensitivity” and “Adaptive Capacity”) and “Exposure”, following the definition of each vulnerability component [11]. The major source of data employed for identifying the vulnerability indicators in this study were obtained from the National Statistical Agency named *Badan Pusat Statistik* (BPS), i.e., *BPS Dalam Angka* (BPS in Numbers) 2015, *Sensus Penduduk* (Population Census) 2010, *Survei Potensi Desa* (Village Potency Survey) 2014 and *Sensus Pertanian* (Agricultural Census) 2013.

4. Results and discussion

West Java province is one of the national production centers of paddy and corn. Production areas of paddy are spatially distributed across the northern and southern areas of the province, with the largest production centers of over 800 thousand tons/year located along the northern coast (i.e., Karawang, Subang and Indramayu). For corn, the largest corn production centers located in Garut with a total production reaching to 600 thousand tons/year (figure 1).

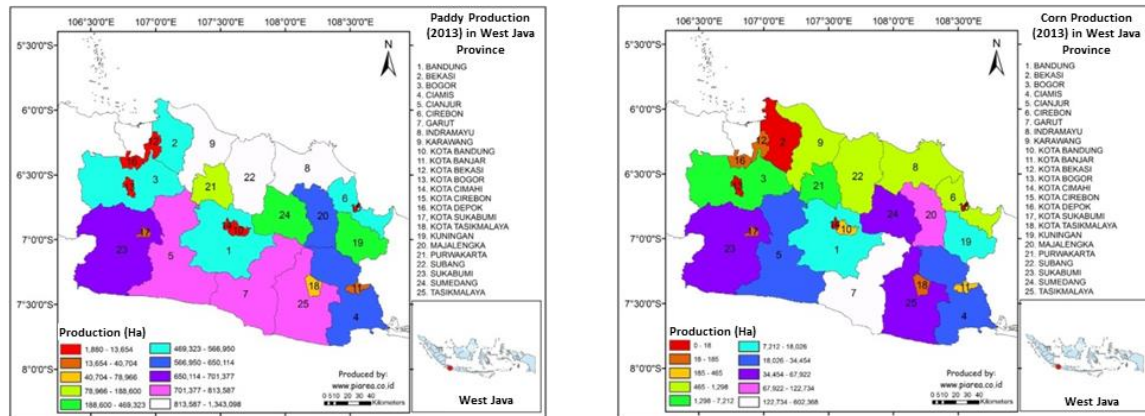


Figure 1. Regional variability of paddy (left) and corn (right) production areas in West Java 2013 [23]

Further exploration in the case study area is directed to understand the diversity of regional climate types. This information can provide information on the climate type for each crop production center. The application of Oldeman climate classification technique suggested that climate types for West Java can be categorized into 12 climate zones. This classification is a little bit different with the classification of Badan Meteorologi, Klimatologi, and Geofisika (BMKG) – Meteorology, Climatology, and Geophysics Agency, whose categorized the West Java into 46 seasonal climate zonation or called as ZOM [18]. The paddy production center of Indramayu comprises three types of Oldeman classification, namely: D3, C2 and C3; whereas, with refer to the BMKG classification, the region can be classified into ZOM 77, 78, 79 and 80. For Garut, the Oldeman climate types are A, B1, B2, C1 and C2, and the BMKG categorizes the region into ZOM 88 and 89 for the year of 2015/2016. Generally, Indramayu and Garut have monsoonal climate pattern, which is characterized by the unimodal monthly precipitation over a year. This pattern suggests that the months of June, July, and August are the dry months, while December, January, and February are the wet months.

The different climate types for the district of Indramayu and Garut; although, the general pattern (i.e., the monsoonal pattern) are the same, reveals that spatial variability of crop productivity can also be explained by the climate types. The Oldeman climate type is applied considering the technique is purposed to classify climate for crop production region [17, 19]. For the purpose of comparison, the Koppen and Schmidt-Ferguson classification types were also applied to the same gridded climate data for the West Java. The classification shows a little different because of the criteria applied for each climate classification; however, the general pattern shows latitudinal direction of climate groups where the southern and norther part of the region exhibit distinct climate types. The climate classification also tells that the district of Indramayu located in the northern area and the district of Garut located in the southern area has different climate types (figure 2).

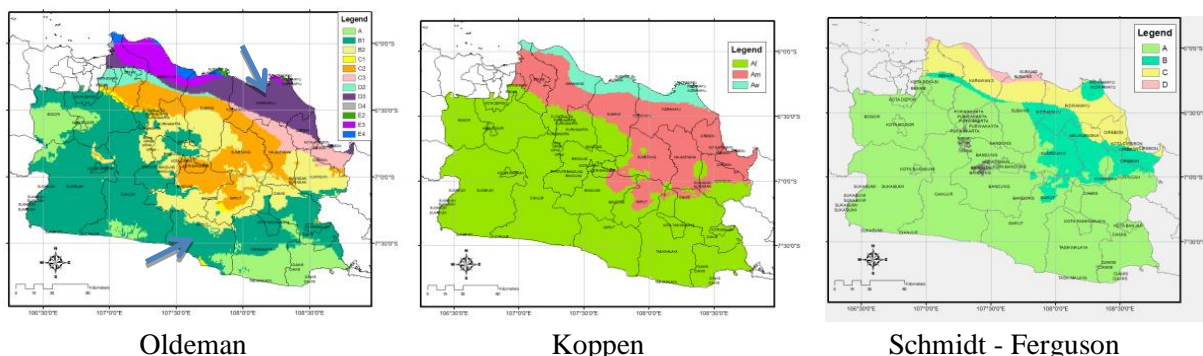


Figure 2. Climate zonation of the West Java determined by the classification methods of Oldeman (left), Koppen (middle), and Schmidt – Ferguson (right) applied to gridded climate data of WorldClim 1971-2000. The legend in the right corner informs about the climate types showed in different colors.

The diversity of climate classification can be the reason for Indramayu and Garut as the major growing areas for paddy and corn, respectively. For Indramayu, the major growing areas of paddy, the areas with the largest productivity are in the sub-district of Widasari (a total production of 78 to 80 kw/ha), and the lowest productivity are in the sub-district of Kandanghaur, Indramayu and Sindang (a total production of ≤ 62 kw/ha). The harvested area in Indramayu are considered lower on the east and the north coast (figure 3); which is reasonable as the two areas are the main areas for industry and government offices. However, the highest productivity areas such as the sub-district of Widasari does not always automatically reflect the highest cropping intensity (CI), calculated based on the proportion of harvested area to the area of paddy fields. The Widasari has the value of CI ~ 2.03 , which means two planting times a year. This CI value is lower than that for the District Gantar whose CI is ~ 3.18 .

As for corn, the productivity of corn production at each sub-district of Garut district ranges from 60 to 80 kw/ha, with the highest productivity in the northern areas. The harvested area of corn in the district are generally considered low to moderate (0-3000 ha), only several areas recorded relatively high harvested area such as the sub-district of Blubur Limbungan (7000 ha) (figure 4). The CI of corn in the district of Garut on average is about 2.82, which means about three planting times a year.

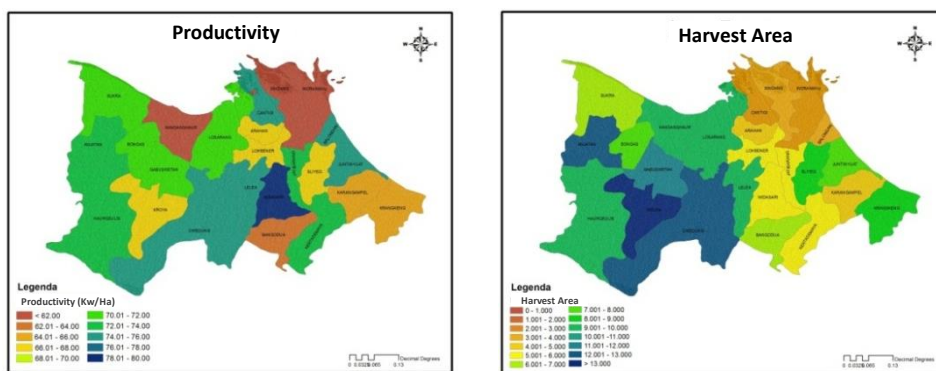


Figure 3. Productivity and harvested area of paddy in the district of Indramayu in 2014. Data source: BPS Indramayu dalam Angka 2015 [22].

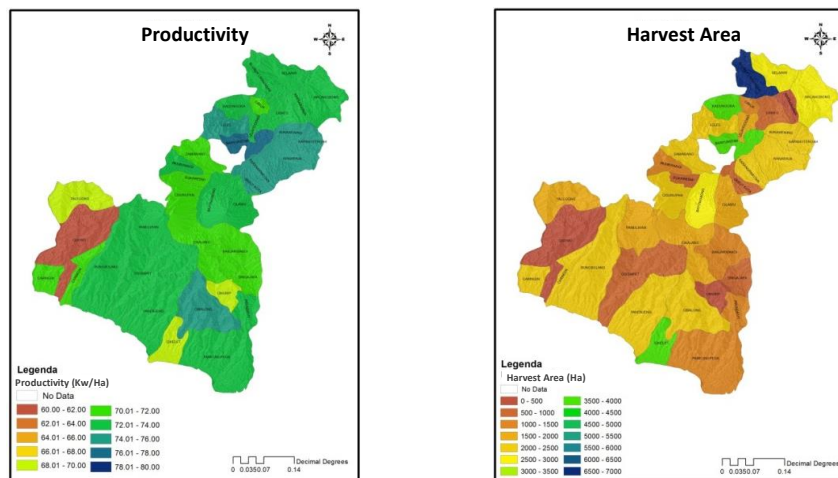


Figure 4. Productivity and harvested area of corn in the district of Garut. Data source: BPS Garut dalam Angka 2015 [8]. Legend color explains the level of productivity / harvested area from high (blue) to low (orange)

Unfortunately, these production centers face serious challenges due to land conversion and erratic rainfall causing difficulty in determining the beginning of growing season. It was reported that the largest conversion rate occurred in 2000 to 2001; about 189,813 hectares of paddy fields were converted into non-agricultural uses [8]. This decline in planted areas is subseted with better farming management and technology purposed to increased crop productivity. However, unpredictable growing season can cause difficulty to farmers and may result in delaying the sowing date. Climate extremes, leading to climate hazards (e.g, drought and floods), also exarcebate the challenges. This challenge, hereafter frequently known as climate risk, is a function of “Hazards”, “Vulnerability” and “Exposure”. Hazards in this context is a function of climate variability and change; whereas, Vulnerability and Exposure are a function of enabling condition surrounding human activities such as socio-economic condition [11].

Understanding the concept of risks, the development of indicators for measuring the component of risks, namely: Vulnerability and Exposure [11], was completed by considering contributed factors to the food supply chain identified in the two crop production centers, i.e., Indramayu and Garut. The identification considers factors contributed to each stage of the supply chain (i.e., production, post-harvest and storage, distribution, and consumption) and the related studies on vulnerability assessment [13, 15, 20, 21]. For example, the statement of Agriculture Minister, Bapak Andi Amran Sulaiman, who said that population densisty including agricultural workers, water resources, and access to agricultural inputs are challenges that should addressed [9] for sustaining crop production. The previous study [13, 20] suggested that crop production is determined by factors such as the sources of family income and agricultural workers to measure vulnerability. The ratio of paddy/corn production per planted area and the ratio of crop production area to agricultural land should be considered as the vulnerability indicators [15]. This identification produced a list of indicators categorized into each stage of the supply chain as presented in figure 5.

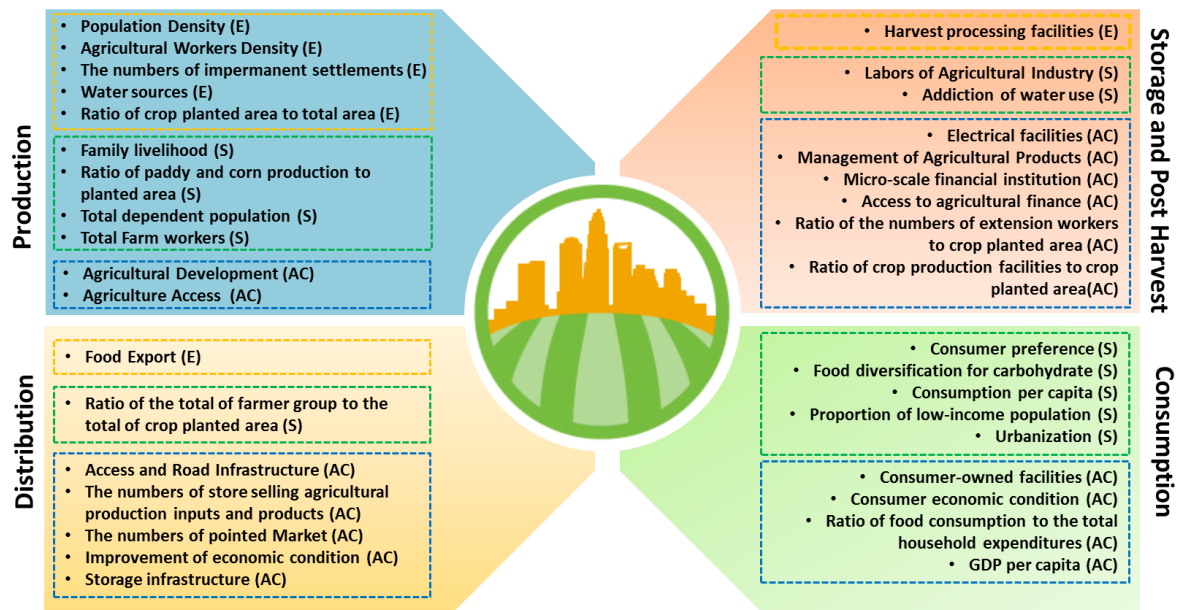


Figure 5. The proposed indicators to measure the level of vulnerability of crop production regions. The abbreviation in the brackets indicated the risk components of E (Exposure), S (Sensitivity) and AC (Adaptive Capacity) as defined by IPCC [11]

5. Conclusion

Agriculture is a sector considered mostly influenced by climate fluctuation. Classification of climate types for the case study (i.e., the West Java) identified that differences in climate type might dictate the commodity grown in the crop production centers. The district of Indramayu, located in the northern area of West Java, and the district of Garut, located in the southern area of West Java, have differences in climate type and major crop commodity grown, namely: paddy for Indramayu and corn for Garut. Unfortunately, the production centers are currently facing challenges due to land conversion and unpredictable growing season. Future climate change may exacerbate this challenge. As an approach to devise proper anticipation strategies, this research derived indicators for Vulnerability and Exposure based on contributed factors to the supply chain of the commodities in Indramayu and Garut. The indicators were developed based on literature review, meetings and discussions with key players of each stage of the supply chain, i.e production, post-harvest and storage, distribution, and consumption. Each stage of the supply chain can be associated with specific vulnerability indicators as proposed in this study presented in figure 5. This information can help further studies focussed on the regional vulnerability assessments, which can be used as a reference study to identify proper interventions required to support the targets of sustaining or enhancing food security.

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