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RESEARCH ARTICLE

Identified vulnerability contexts for a paddy production assessment with climate change in Bali, Indonesia

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Indonesia is one of the countries that is most vulnerable to climate change. As a small Indonesian island, Bali is likely to also be affected by climate change impacts, including rising sea levels, drought, and flooding, which will also impact on its paddy production. This paper shows how the focus area of vulnerability assessments in Bali has been identified, based on multiple assessments including literature reviews, statistical assessment, stakeholder and policy assessment, and interviews with farmers. A project team applied a six-step process to identify issues linked to climate change, the purpose and system of vulnerability assessment, potential risk/harm in context, and potential variables for a further assessment. The team identified paddy production as a significant issue, and the purpose and system was the Presidential Decree No.5 on paddy production. Significant concerns linked to paddy production included droughts, land use change, and potential variables for vulnerability assessment such as water level and the price of rice. This paper suggests how adaptive measures should be implemented to handle paddy production in a changing climate. The results of this paper were used by a vulnerability assessment on rice paddy and climate change [Takama, T., Setyani, P., & Aldrian, E. (2014). Climate change vulnerability to rice paddy production in Bali, Indonesia. In W. Leal Filho (Ed.), *Handbook of climate change adaptation* (pp. 1–23). Berlin: Springer].

Keywords: vulnerability; adaptation; agriculture; Asia

Introduction

The devastating impact of climate change is already evident in Indonesia. The combination of high population density and a high level of biodiversity, together with its more than 15,000 islands and a coastline that has (a staggering total of) tens of thousands of kilometres, make Indonesia one of the most vulnerable countries to the impact of climate change. As a small island of Indonesia, Bali is likely to be affected by climate change, impacting various aspects such as rising sea level, drought, flood, as well as paddy production.

The purpose of this paper is to show how a project team identified the focus area of vulnerability assessment in Bali based on multiple assessments, including literature reviews, statistical assessment, stakeholder/policy assessment, and interviews with farmers. The focus areas have to be applicable not only to Bali Island, but also to the rest of Indonesia in order to make this study scalable in the future. Through a six-step process, the project team identified issues concerned with climate change, the purpose and system of vulnerability assessment, potential risk/harm in context, and potential variables for a further assessment.

According to Harvey, there are 10 steps to complete a vulnerability assessment to create vulnerability indicators (Harvey et al., 2009). This paper applies the first six steps, namely identifying a range of issues to the potential variables (Figure 1). Reviews on the existing reports identified a range of issues. The purpose and system of vulnerability assessment and potential harms were identified in stakeholder meetings and policy assessment in Bali. The findings from these qualitative assessments were supported and revised by statistical assessment. The findings were reviewed by interviews with farmers, and the interview results helped to recognize potential variables to assess vulnerability for the paddy production issue in climate change. A more detailed vulnerability assessment on rice paddy and climate change was conducted by the same project team based on the findings of this paper (Takama, Setyani, & Aldrian, 2014).

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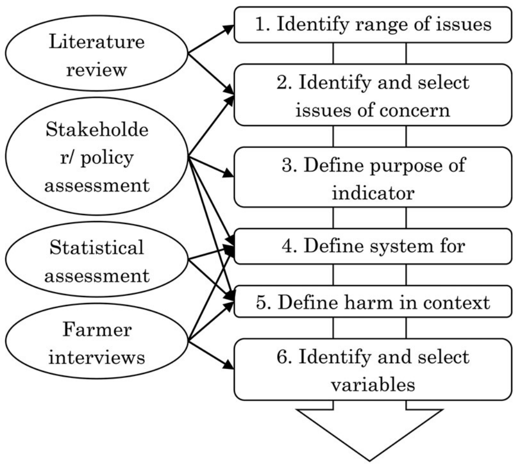

Figure 1. Process of identifying issues, purpose, system, context, and variables for a vulnerability assessment. Step 1 identifies the range of issues. Step 2 identifies and selects the issue of concern. Step 3 defines the purpose of vulnerability assessment. Step 4 defines a workable system. Step 5 defines harms in context. Step 6 identifies and selects variables. This approach starts with finding relevant factors affected by the identified harms, rather than studying general contexts of exposure units (Hinkel, 2011).

Backgrounds on climate change adaptation and vulnerability in Indonesia

Vulnerability concepts

The IPCC gives the most often quoted definition of vulnerability:

> Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (Parry, 2007, p. 883). Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

The vulnerability of climate change has been defined differently (Adger, 2006; Birkmann, 2007; Füssel, 2010; see e.g. Kelly & Adger, 2000; O'Brien, Eriksen, Nygaard, & Schjolden, 2007), but it is distributed between outcome vulnerability and contextual vulnerability (O'Brien et al., 2007) (Figure 2). Outcome vulnerability defines vulnerability as the compound result of impact assessments and adaptive capacity. Contextual vulnerability assumes that vulnerability is determined by the potential characteristics of issues, context, purpose, and system. In either definition, vulnerability changes when the context of issues, context, purpose, and system change. Therefore, it is important to identify these before a vulnerability assessment is conducted.

Climate change in Indonesia and Bali

Indonesia is the largest and widest archipelago country in the world and is known as a tropical maritime continent country (Neale & Slingo, 2003; Ramage, 1968). In Indonesia, the trend of significantly increasing air temperatures has been observed in many parts of the region (Diffenbaugh & Giorgi, 2012). Indonesia is among the countries that will be significantly affected by accelerated global climatic change (Kawanishi, Takama, Ogawa, & Takahara, 2011). Bali Island in Indonesia, which is located south of the equator, is approximately 153 km wide and spans approximately 112 km north to south. The total area of the island is 5636.66 square kms, which is 0.29% of the total area of the country. The province is divided into eight regencies (Figure 3).

There is some evidence showing rainfall patterns have changed as per data between 1951 and 2000 (Meteorology, Climatology and Geophysics Agency (BMKG), 2010). The onset of the rainy season and dry season has been delayed or advanced, depending on locations. In Java, some areas have become wetter while others exhibit an opposite pattern as shown in Figure 4. The map is dominated by white to yellow colours. The white colour means no

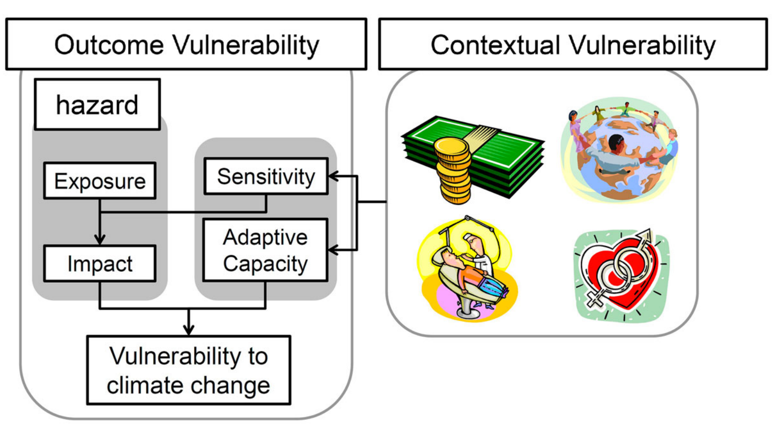

Figure 2. Vulnerability concepts and importance of finding issues, context, purpose, system, etc. Outcome vulnerability defines vulnerability as the compound result of impact assessments and adaptive capacity. Contextual vulnerability assumes that vulnerability is determined by the potential characteristics of issues, context, purpose, and system.

significant trend of dry spells. The yellow colour means significant positive trend with dry spells increasing to 5 days for 10 years. Figure 5 shows the trend of maximum wet spells (maximum number of consecutive days with rain). The trend value ranged from –2 (red) to 1 (blue) day/10 years. The wet spell trend varies with location. Some locations have become wetter and others have become drier or have remained unchanged. Also, the study demonstrated some areas have changed in the pattern of heavy rain (rainfall more than 50 mm/day).

Bali Island has a high possibility of disturbance within the season (Makmur, 2011). As shown in Figure 6, precipitation in each month has a high level of disturbance based on 30-year data. For example, if rainfall decreases significantly, a wet season becomes very dry and if rainfall increases significantly, a dry season becomes very wet. That is, wet and dry seasons may flip, causing significant problems in water-related sectors, including agriculture.

Development priority in Indonesia

Adaptation to climate change is a new theme in the development of country as many vulnerability and adaptation issues are related to development (Adger, Huq, Brown, Conway, & Hulme, 2003; Schipper, 2007; Smit & Pilifosova, 2003). Therefore, it is essential to check and reflect on the development prioritieswith vulnerability assessments. The government has updated the recent mid-term development plan. Two strategies outlined below are key policy priorities affecting the direction of the current government and share a relationship with adaptation issues in Indonesia (Bappenas, 2010b). The 11 national priorities are aimed at addressing the challenges faced by the nation in the upcoming period, including reform of the bureaucracy and governance, education, health, reduction of poverty, food security, infrastructure, investment climate, business climate, and environment and management of natural disasters (Bappenas, 2010b, pp. I-49–57). For example, food security as a priority pertains to continuing the revitalization of the agricultural sector for realizing self-reliance in food, increasing the competitiveness of agricultural products, increasing the income level of farmers, and conserving the environment and natural resources. Environment and management of natural disasters as a priority aim at the conservation and utilization of the natural environment that supports sustainable economic growth and increases the welfare of the people, accompanied by the control and management of disaster risks for anticipating the impacts of climate change.

Previous achievements on vulnerability assessment in Indonesia

Climate change vulnerability affects various sectors in different ways. Also, the climate change vulnerability issues have to take long-term economic and development trends into account, including industrialization and urbanization; otherwise, the adaptation to climate change based on vulnerability assessments may become maladapted. Therefore, vulnerability assessments have been carried out in multiple sectors alongside development planning.

Several agencies and departments in Indonesia have conducted studies related to vulnerability assessment including Indonesia Climate Change Sectoral Roadmap (ICCSR; Bappenas, 2010a), Indonesian Climate Change Trust Fund (ICCTF-BMKG, 2011), National Action Plan of Climate Change (PU, 2007), Indonesia Country Report: Climate Variability and Climate Change, and Their Implication (UNDP, 2007), and IPCC National Communication reports (KLH, 2009). In these reports, the most common areas of vulnerability and adaptation assessments include agriculture, coastal zone, water resources, human health, and forestry.

Methods

This research was conducted based on series of multiple qualitative and quantitative methods (Onwuegbuzie & Leech 2005; PROVIA, 2013). First, literature review and qualitative interviews and focus group discussion were used to identify issues and problems and determine the direction of the assessment as qualitative methods are particularly useful for the initial stage of assessment where the direction of the assessment has not been determined and there are too many possibilities to explore, but adequate amounts of information are not available (Marsland, Wilson, Abeyasekera, & Kleih, 2000). The qualitative assessment was conducted with local famers in Bali as well as government officers, including Regional Development Agency (BAPPEDA), and the Agricultural Agency in Bali. The literature reviews are based on national and regional policy reports, including five-year national development plan, National Communications, Mid-Term Development Plan, Bali Green Province, and Bali Action Plan Facing Climate Change. Others source are mentioned in the subsection below.

Second, qualitative methods are applied to narrow down and define issue, purpose, and harms in the context. Agricultural census and other census stored by the Central Agency on Statistics, Indonesia (BPS) was used for statistical analysis. Third, qualitative methods, such as in-depth interviews and expert consultations, were applied again to confirm the findings of the assessment as well as to identify potential variables for further vulnerability assessment. The whole assessment process was divided into six stages as described below.

Six-step identification process

After reviewing relevant projects, the project team decided to apply a vulnerability assessment process developed

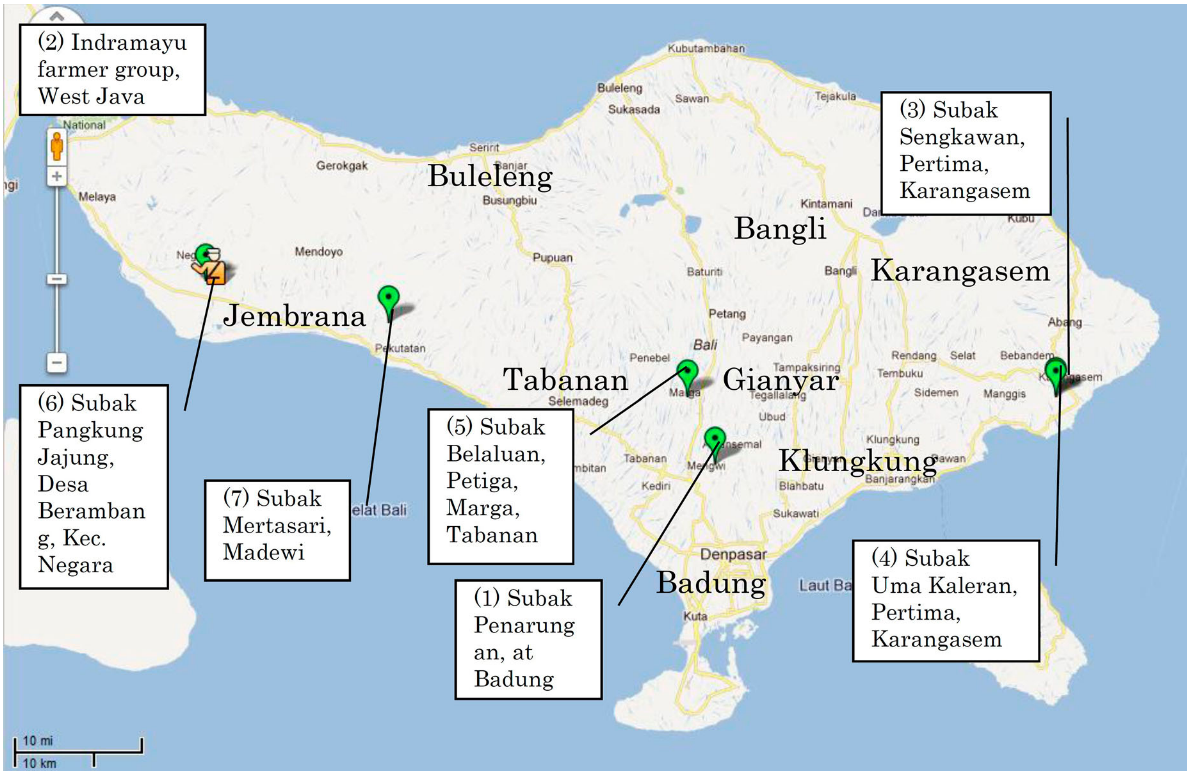

Figure 3. Bali Island is located south of the equator, is approximately 153 km wide and spans approximately 112 km north to south. The province is divided into eight regencies. Marker in the map indicates an area's socioeconomic data survey and interviews were conducted to estimate adaptation capacities.

during a study in the Harvey et al., 2009. The process is used in more developed countries in larger areas than this project. However, the EU study was aimed to be used by policy-makers and was designed to make a vulnerability index. These two aims are the same as those of our project, which is also aiming to scale up to all of Indonesia after the current Bali assessment. Therefore, the process was a suitable one to apply. Nonetheless, the project team

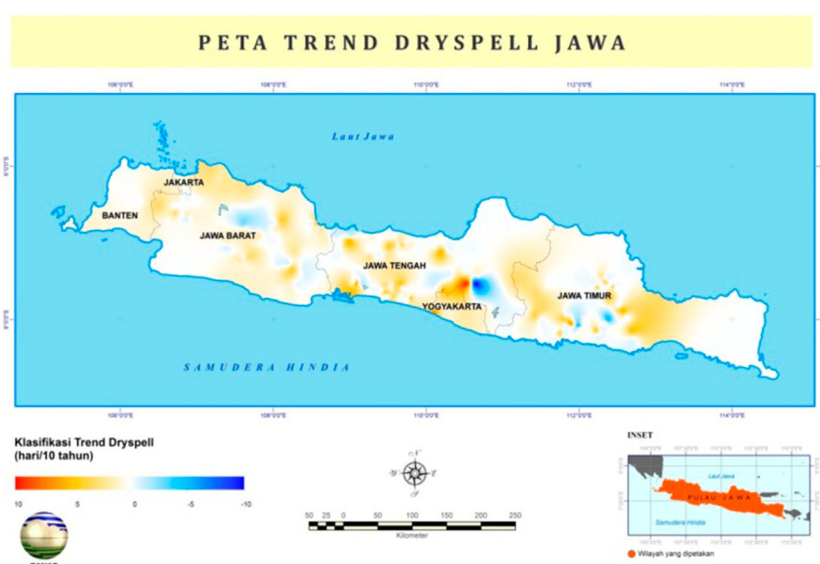

Figure 4. Trend of dry spell in Java. The map shows how many days dry spells have increased in Java. Red colour indicates an increase by 5 days and blue colour indicates a decrease by 5 days in 10 years. (Meteorology, Climatology and Geophysics Agency (BMKG), 2010).

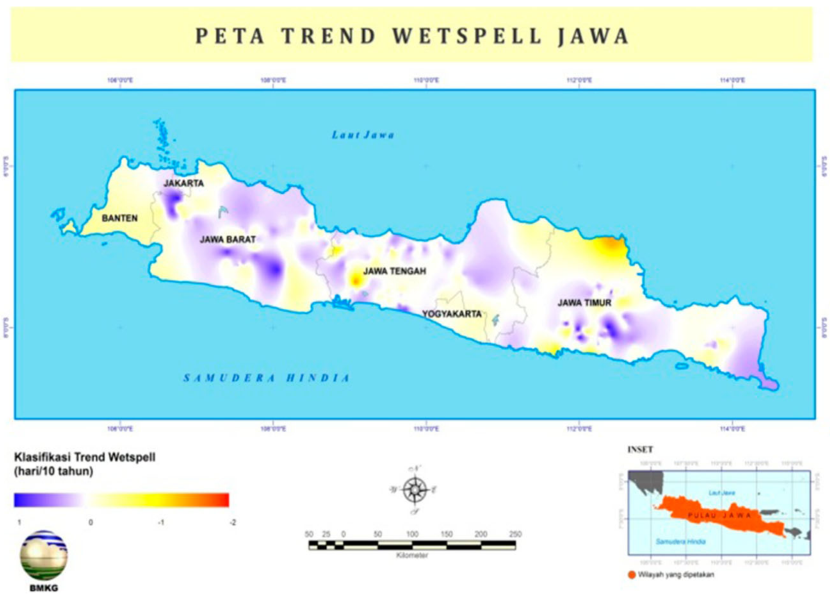

Figure 5. Trend of wet spell in Java. The map shows how many days wet spells have increased in Java. Blue colour indicates an increase by 1 day and red colour indicates a decrease by 2 days in 10 years. (Meteorology, Climatology and Geophysics Agency (BMKG), 2010).

revised the process to fit the context of Indonesia as well as the capacity development project within government offices. The six steps implicitly have a number of iteration and refinement issues in the process, and different degrees of detail were required for different types of assessments. The following sub-sections provide a description of each step in the process:

Step 1. Identify range of issues

The first stage was about setting the general context and nature of the problem in Bali, but also those that are applicable in Indonesia. This was mainly done by literature reviews of policy documents.

Step 2. Identify and select issue of concern

This step made the project team focus on specific issues. Initially, more than one issue was identified as relevant and important to target users through the literature review, but the selection process was narrowed down to the issue of concern in stakeholder meetings and through policy assessment.

Step 3. Define purpose of vulnerability assessment

A key process in this step was to tie in the policy objectives, actions, and targets of users, as different vulnerability assessments should be needed for different purposes. Defining a purpose shaped the structure of the project and helped determine the rest of the identification steps. This was carried out in stakeholder meetings and with policy assessment as well as other meetings with local authorities

Step 4. Based on purpose, define workable system

The project team defined a system as a policy framework we worked within to determine the issues and identify the purpose in previous steps. Moreover, a scientific framework was used to refine the system by making explicit the assumptions used in a future vulnerability assessments. For example, the three pillars of IPCC vulnerability definition and WFP's food sustainability. This process was conducted together with Step 3, but the paper keeps the two steps separate to be consistent with the EU process.

Step 5. Define harm in context

A vulnerability assessment requires a definition of what harm means for the system of interest and subject exposure units in the system (Bisaro, Wolf, & Hinkel, 2010). Potential harms were mentioned in the previous steps in literature, meeting, and policy assessment, but statistical assessments were used to confirm and revise these harms.

Step 6. Identify and select variables

As well as nominated variables indicated in the previous steps, this paper demonstrates the selection process of variables through farmers' interviews. This approach starts with finding relevant factors affected by the identified harms, rather than studying general contexts of exposure units (Hinkel, 2011).

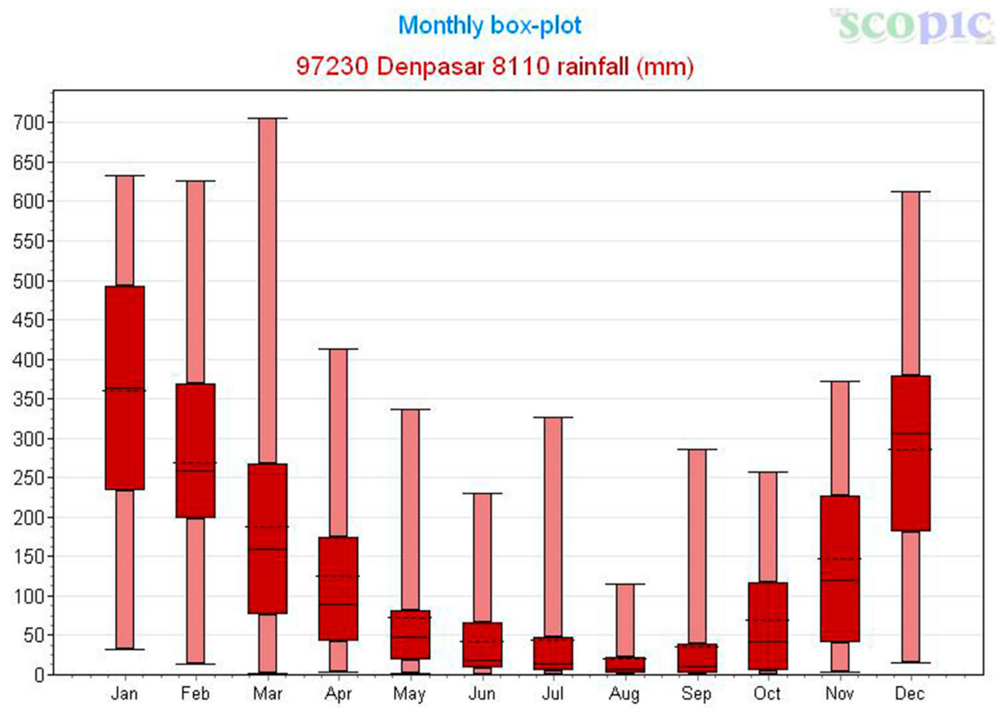

Figure 6. High possibility of disturbance within the season. Each box plot shows 50%, min and max of data. The box plots show that the variability of precipitation is high; therefore, a rainy season may seem like a dry season and vice versa. (Makmur, 2011).

Results

Step 1. Identify range of issues

Literature review identified and roughly selected the range of important issues related to vulnerability assessments in Bali and Indonesia. In the 12 policy reports, 5 sectors were referenced repeatedly, such as agriculture, water resources, coastal zone, forestry, and human health, which are considered as the most common areas of vulnerability and adaptation assessments. The main sources of information are five-year national development plan (Directorate of Coasts and Ocean, Indonesia, 2009), poverty reduction strategy plan (Bappenas, 2010a), National Communications (Bappenas, 2010b), and national climate change plan-related documents as well as other eight official governmental reports (Bappenas, 1999; KLH, 2001, 2004, 2009, 2010; UNDP, 2006). These documents present development and adaptation related strategies, activities, and measures. Based on these mainstream concepts (Huq et al., 2004; Huq & Reid, 2004: Klein et al., 2007), this report uses development-related measures as potential adaptation measures. Our assessment in the five sectors, throughout policy reports, identified the sets of adaptation measures and vulnerability assessment needs. There are overlaps in adaptation measures in different reports, so these adaptation measures are generalized as a set. For example, improvement of water management in rice production is mentioned in four reports and promotion of water saving is mentioned in five reports. The numbers of sets of adaptation measures identified are:

- agriculture sector has 22 sets;
- water resources sector has 20 sets;
- coastal zone sector has 15 sets;
- forestry sector had 12 sets; and
- human health sector 11 sets.

The agriculture sector needs more adaptation supports to cope with the impact of climate change. Identified potential adaptation supports are 22 sets of measures[1], for example, ‘the necessity in a drought early warning system’ in National Action Plan 2007 (Ministry of Public Work (PU), 2007) and ‘requirement in the impact study of climate change to the cultured fisheries’ in ICCSR (Ministry of Development (Bappenas), 2010a). Moreover, President Yudhoyono stated, ‘ … the government could focus and prioritize its resources to address the key issues of food insecurity … ’ in Kemtan’s food security report (WFP & Ministry of Agriculture (Kemtan), 2009).

Furthermore, paddy production has a status to be the most vulnerable sector to climate change, since agriculture is sensitive towards the climate conditions in the related areas in Indonesia (Ministry of Environment Indonesia (KLH), 1999, pp. 2–13). Major decreases in rainfall in dry seasons will have an impact on food crops production. The current cropping pattern might not be feasible in the future. At present, the cropping pattern used in most rice-growing areas in Indonesia is a rice-rice two-crop system. The second planting depends heavily on irrigation water. Under extreme drought years, the availability of irrigation water is becoming very limited and this will normally cause a huge rice production loss. Under a changing climate, drought may be more frequent and the dry season may last for longer periods. Indonesian farmers may face more crop failures if they use the rice-rice two-crop system.

Step 2. Select issues of concern

The local stakeholder meetings provided opportunities to confirm the issues studied in the literature. All participants noted, in particular, considerable concern about and increasing research needs on food security relative to climate change. The vulnerability assessment from the sub-project will be aiming at improving our basic understanding of vulnerabilities as well as key elements related to the climate system, impacts, and response measures in the paddy production of Bali province. In the meeting, the project team developed 'Climate Change Sensitivity Matrix for Paddy production' (Figure 7). The participants agreed on the two elements: (1) focus on farming land, fisheries, water quality, and quantity to find the first sector of a formal vulnerability assessment, and (2) from the perception of policy-makers, drought, flood, and torrential rain are more dominant hazards in Bali for the three potential sectors. The following meeting with representatives from national ministries confirmed the focus areas. Through scientific activities, the participants recognized the valuable role of vulnerability assessment to improve the policy-making process integrating the adaptation to climate change in Indonesia. It was agreed that the joint involvement of national policy-makers should be encouraged in areas of common interest.

To determine the first case of a vulnerability assessment, policies related to paddy production and climate change were further assessed with two assessments. The first assessment summarized the focus areas identified during the first stakeholder meeting. The assessment started by identifying key issues in climate change vulnerability with food and water security. Besides information gathered during stakeholder meetings, policy reports from Bali development agencies were used for the assessment, namely Mid-Term Development Plan, Bali Green Province, and Bali Action Plan Facing Climate Change (Development Agency (BAPPADA) Bali, 2007, 2009, 2010). The second assessment summarized the existing policy matters in Bali. It is important to assess the quality and context of policies related to each livelihood, but the assessment showed that paddy agriculture had many potential risks, important roles local authorities needed to play, and aggregated potential to other sectors. For example, paddy firming is strongly linked with the tourism sector and issues with land conversion. Also, the implementation of organic farming will support a better local ecosystem. There are a number of policies discussed and implemented in the ocean fishery sector, but aggregation with other issues and sectors seems limited. With further discussion with local authorities, the project team decided to work from paddy production while we kept options to assess other agriculture and water sectors later in the viewpoint of paddy production.

Steps 3 and 4. Define purpose of indicator and a workable system

Stakeholder meetings were also used to identify purpose and system as well as potential risk, and contexts. By the time we had the second stakeholder meeting, it became clear that the vulnerability assessment in this project is to support local authorities because of their willingness to participate in the assessment and the general nature of an ODA project.

The project agreed to work for the vulnerability assessment related in paddy production as the first case. Therefore, the purpose of a vulnerability assessment came to support the operation of policy-makers/local authorities namely, BMKG, BAPPEDA, and the Agricultural Agency in Bali. The project team and policy-making agencies explored a list of policies as a system the team works for. Then, we decided to use Presidential Decree No. 5 'Protection of National Rice Production in Facing Extreme Climate Condition' as our system (Government of Indonesia, 2011). Decree No. 5 is the risk analysis of extreme climate impact on production and distribution of rice and disseminating the information to farmers. Decree No. 5 was issued in 2011, and each province was requested to report its assessment periodically to the national government. The team and policy agencies chose the decree because of relevancy to the purpose, urgency for the response, and strong needs from the agencies.

Step 5. Define harm in context

We used quantitative assessments to define potential harms in the context of paddy production, especially with paddy production, in addition to the qualitative assessment by stakeholder meetings and policy assessments. Several potential harms were already mentioned above, and in this section, this paper demonstrates the identification process of the largest potential climate and non-climate harms, namely drought and land use.

A spatial analysis shows rain pattern changes of 46% and 54% in Bali areas in wet and dry seasons between the 1970s and 2000s (Prasetya & Novianti, 2011). As a result of this, our assessment showed that soil climate suitability for paddy production might be reduced by 20%

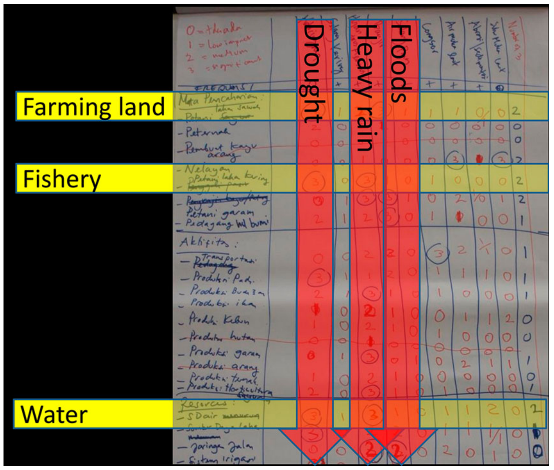

Figure 7. Climate change sensitivity matrix for paddy production. The project team determined farming land, fishery, and water as the most vulnerable sectors and drought, heavy rain, and floods as the most severe weather-related disasters while developing the matrix.

between the 1990s and 2000s (Figure 8). The research outcomes reconfirmed the possibility of climate change in Bali as well as the strong possibility of paddy insecurity with climate change. The reduction of suitability is mainly due to the decline of precipitation. The north and north east of Bali have been getting drier based on BMKG's analysis. Therefore, drought is potentially the number one concern within the weather-related disasters for paddy production.

Statistical assessments show another potential harm related with land use. Generally, the land use for agriculture shrank from 2000 to 2008, although it is fluctuated around 2006 (Table 1). This means that land conversion from agricultural to non-agricultural uses occurred in 2000–2008. Land use change needs some preparation, so the fluctuation is likely to be due to measurement or reporting errors, but further investigation is needed to confirm this assumption. Particularly as Denpasar and Badung are tourism areas, land conversion from agricultural use to non-agricultural use is because of economic reasons. The sale of agricultural land to entrepreneurs from outside Bali has increased (Development Agency (BAPPADA) Bali, 2007).

Most agriculture land is used for non-paddy agriculture, including maize, soybeans, mungbeans, timber, estate crops, and grassland. Agricultural land use for paddy is shrinking except in Bangli Regency and land use for non-paddy agriculture is increasing slightly in most regencies except Bangli, Denpasar and Tabanan Regencies (Table 1), and this leads to the reduction of harvested areas, which is the multiplication of land area for paddy and the number of production cycles per paddy (Table 2), for example, if a paddy area produces rice twice a year, the harvested area is double the paddy area.

In general, the production of paddy has decreased from years 2000 to 2005 and then increased slightly from years 2006 to 2008. The decline in paddy's production is in line with the shrinking of harvested areas for paddy. In contrast, the production rate has been increased; therefore, it negates the reduction of total yield level. From years 2000 to 2008, the harvested area has been reduced 7.1%, productivity rate increased 9.5%, and production size increased 1.6%. The paddy production may not be able to rise or may even shrink in the future if paddy areas are further reduced, or production rate and production cycle are reduced by climate change. Therefore, inappropriate land use may harm the production of paddy.

Step 6. Identify and select variables

Potential variables to conduct vulnerability assessments for paddy production under climate change had been mentioned in the stakeholder meetings and estimated through policy and statistical assessments. This section shows the selection of variables, especially in relation with land use change through interviews with paddy farmers (Figure 3).

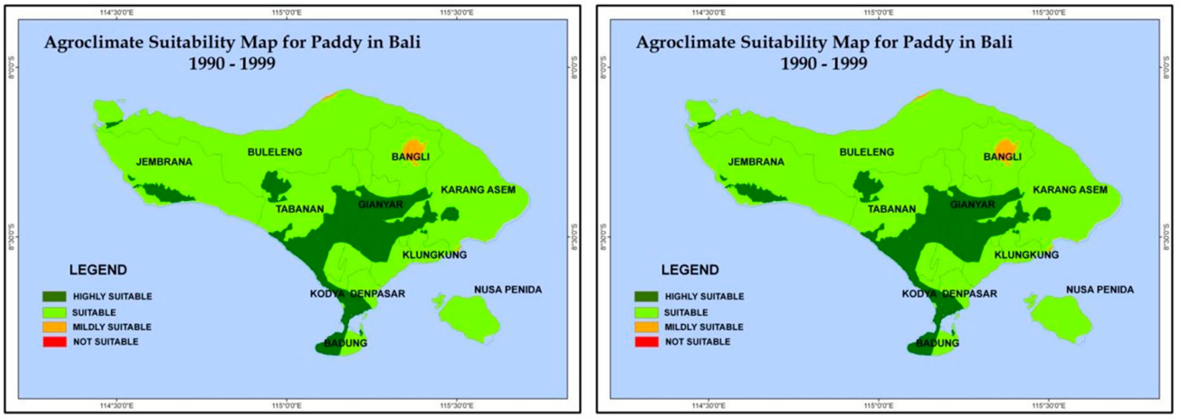

Figure 8. Reduction of crop suitability (Prasetya & Novianti, 2011). The green colour indicates good suitability for rice paddy production and the orange colour indicates less suitability. The area of suitable area has decreased in the last 20 years.

Table 1. Area of land by type of use in Bali 2000–2008.

Year	Land use for agriculture – paddy (ha)	Land use for non-paddy agriculture (ha)	Land use for non-agriculture (ha)
2000	85,776	267,794	210,097
2001	84,860	268,258	210,551
2002	83,562	268,948	211,155
2003	82,644	269,473	211,549
2004	82,089	269,411	212,134
2005	81,207	273,332	209,127
2006	80,997	273,386	209,283
2007	81,235	271,704	210,727
2008	81,482	274,755	207,429

Note: More land is used for non-paddy and non-agricultural purpose. Between 2000 and 2007, the rice paddy area has shrunk by roughly 5% in Bali.

The interviews were carried out to investigate how paddy production is affected by climate- related disasters, considering other related issues, namely changing to crop agriculture and land conversion. Also, the interview looks at the farmers' behaviour for the weather-related disasters and rationale to changes in farming practices.

First, the interview found four classifications of land use/farming practice. A 'rice intensive' subak is the subak that has sufficient water and its annual cropping cycle is paddy – crop – paddy or paddy – bera (empty) – paddy. A 'rice and crop balanced' subak is located relatively in dry areas or near a downstream of a main channel. The cropping cycle we have observed under this category is paddy – crop – bera (empty). The 'plantation' subak plants cash crops such as coconuts, cacao, and other fruits and vegetables, but not rice.

The project team found that the factors which affect the decision-making on long-term cropping cycle and land use are water level, the relative price of rice and alternative crops, climate especially rain, insect problems, and governmental policies (e.g. extension agents, tax, subsidies), and subak roles (e.g. allowance to change crop cycle), work amount, and opportunities for the second or alternative jobs, and lack of successors.

In general, people consider the sufficiency of water as one of the key factors that define farmers' behaviour. Several interviewees changed their land function from paddy agriculture to other agriculture because of water insufficiency. In a few subaks, a water problem has resulted since the water was used not just for farming but also for settlement. In Subak Belaluan and Subak Pangkung Jajung, interviewees said that the shortage of water was judged just from their harvest failure experience. Relating to water sufficiency in a subak, climate – especially rain – affects the farmers' decision on land use and crop patterns, although the path of influence could be different amongst subaks. Subak Pangkung Jajung is partially rainfed, so small precipitation negatively affects the paddy production directly where water in the subak irrigation is insufficient. Farmers in all subaks and farmer groups mentioned that too much rain would increase pests such as the brown hopper, so too much rain also affects the harvest negatively.

The relative prices of rice and alternative crops are other key factors mentioned by multiple subaks. The value of cocoa and clove could reach 5–10 times higher and the vegetables around two times higher than paddy in Subak Mertasari and Subak Belaluan. Moreover, a price for land for housing has a similar affect as the price of alternative crops in Subak Pangkung Jajung. Twenty per cent of the subak has already converted to housing because farmers need cash to send their children to school.

Last, subak rules may prevent the land use change in some subaks. Selling subak lands to outsiders is restricted in Subak Sengkawan and Subak Uma Kaleran. Other subaks visited do not restrict changes, for example, from paddy to cocoa plantation or paddy to housing. Moreover, subak members have to follow the group decision on paddy or crop choice as long as they practice paddy agriculture.

The land use might change from farming to another purpose such as housing and tourism. A 'land converting' subak is limited to a small fraction of all subaks we visited except Subak Pangkung Jajung. Statistical data from BPS support this trend. For example, the members of a village or community/group have to own all land of their subak and are not permitted to sell land to outsiders in Subak Sengkawan and Subak Uma Kaleran.

Identified issues, purpose, system, context, and variables

Through the series of assessments, we identified issues, purpose, system, context, and variables for the vulnerability assessment of climate change in Bali that are applicable to other parts of Indonesia. The outcome is summarized in Figure 9. Reviews on previous climate change vulnerability-related projects confirmed that Indonesia is one of the most vulnerable countries. The assessment showed that agriculture is one of the most vulnerable areas and paddy production is an important issue in Indonesia. Within the paddy production issue, the first stakeholder meeting focused on paddy, fishery, and water sectors.

Table 2. Total harvested area, production rate, and production of paddy in Bali, 2000–2008.

Year	Harvested area (ha)	Production rate (quintal/ha)	Production (ton)
2000	155,049.00	53.33	826,838.00
2001	147,942.00	53.35	789,232.00
2002	148,025.00	54.70	809,688.00
2003	145,294.00	54.60	793,260.00
2004	142,663.00	55.00	788,361.00
2005	141,577.00	55.00	785,481.00
2006	150,557.00	56.00	840,891.00
2007	145,030.00	58.00	839,775.00
2008	143,999.00	58.37	840,465.00

Note: The production level changed, but still maintained at a stable level because changes in the area and the production rate cancelled out. The harvested area has reduced 7% and the production rate has increased by 8%.

Following assessments with policies and studies of statistical data revealed that paddy agriculture was the most appropriate sector in Bali, and it would be most effective to work with paddy first as it would have more aggregation potential with other sectors, including crop agriculture and water sectors. The decision to start the assessment with paddy agriculture was confirmed in the second stakeholder meeting and agreed upon with the governor of Bali province. At the same time, our policy assessment and discussion with stakeholders confirmed use of presidential decree No. 5 as our framework system (Government of Indonesia, 2011). Statistical assessment proved drought, land use change, and potential flooding as potential harms in this context. Interviews with farmers established potential variables, especially within the issue of land use change. For example, the variables that might influence decisions of farmers include water level, rain, prices of rice and alternative crops, and land price, policies, and subak rules.

Discussion

Sequential vs. multiple approaches

The identification process is the process of narrowing pertinent areas. As a result, we had to give up several issues. For example, we mentioned fishery and water sectors as potential areas of interest in Step 2. However, these sectors are, at this moment, not considered as the project team decided to focus on the paddy sector. In any research or development project, it is important to prioritize and focus a smaller number of issues as our activities are limited by time, finances, and human resources (Patton, 2005; Tranfield & Starkey, 1998).

On the other hand, some scholars discuss the importance of the multiple sector approach, which considers the several sectors simultaneously; otherwise, resources for adaptation can be misused or lead to maladaptation (O'Brien et al., 2004; Quinn, Ziervogel, Taylor, Takama, & Thomalla, 2011; Takama, Ziervogel, Taylor, &

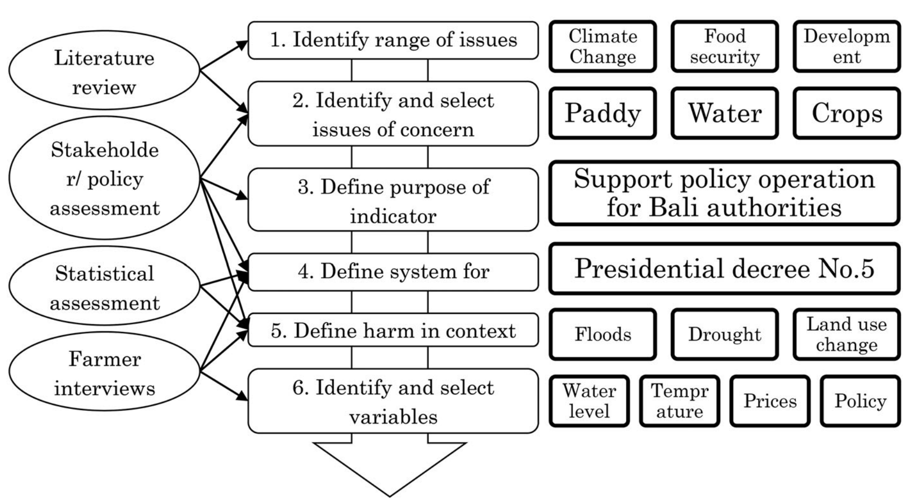

Figure 9. Identified issues, purpose, system, context, and variables for the vulnerability assessment of climate change in Bali/Indonesia. Paddy, fishery, and water sectors are areas of concern in Indonesia. The project decided to focus on rice paddy. Presidential Decree No. 5 is used as our framework system. Statistical assessment proved drought, land use change, and potential flooding as potential harms in this context. Interviews with farmers established potential variables.

Thomalla, 2010; Ziervogel, Taylor, Thomalla, Takama, & Quinn, 2006). For example, if the public work agency and the agricultural agency do not coordinate the development of their irrigation system, one agency may build an irrigation system, where another agency might consider it not necessary to adapt to potential droughts in the future (Coward, 1980; Uitto & Duda, 2002). The team found that working in the rice paddy sector would also help other sectors namely crops and water sectors and previous research supports the argument (Guerra, 1998; Viala, 2008), so we decided to focus on the paddy first before carrying assessments on other sectors.

Moreover, although a multi-sector assessment is good to understand comprehensive vulnerability and adaptation measures (Heltberg, Siegel, & Jorgensen, 2009; VijayaVenkataRaman, Iniyan, & Goic, 2012), it may be necessary to separate adaptation measures amongst agencies to implement the measures in Indonesia and many other countries as a government needs to allocate a budget amongst agencies (Eaton, Kaiser, & Smoke, 2011). When an assessment found that drought is severe for multiple sectors and found an irrigation system as the best adaptation measure for these sectors, the next step will be to coordinate which agency will be working on the implementation (Berger, Birner, Mccarthy, DíAz, & Wittmer, 2007). The logic of the implementation is beyond the objective of this paper, so this paper does not discuss it further, but the process will be complex and complicated. To be a practical development project, it was more appropriate and manageable to carry out an assessment on one sector at a time and work with specific agencies.

Practical implication for paddy production in Bali/Indonesia

The objective of this paper is to show how to focus on important issues, purpose, system, and context and variables to carry out a vulnerability assessment. Then, the next logical step will be to carry out a vulnerability assessment, and some detailed vulnerability assessments have been developed based on the findings from this paper including the vulnerability assessment on rice paddy and climate change (Takama et al., 2014). However, the identification process in this paper can be considered as a rapid vulnerability assessment without the details of spatial components and the project team already found key issues. It is clear that food security is one the most vulnerable areas under climate change in Bali and Indonesia (ICCTF-BMKG, 2011; Lobell et al., 2008). This paper pointed out there are strong possibilities to reduce paddy production in Bali. Both the domestic government including the Bali authority and an international aid community can support the vulnerability of paddy production in Indonesia/Bali.

As well as ordinal adaptation measures including irrigation and seed selection, Bali has a unique farming practice, which can be used as adaptation measures (Lansing, 2007; Stoffle, Toupal, & Zedeño, 2003). Indonesia's government, as well as the Bali authority, is promoting organic farming (Martojo, 2012; Moeskops et al., 2010). There are some evidences from farmers' interviews saying the productivity has increased when farmers adopted the organic farming, so that this measure may have a potential to improve general adaptive capacity instead of moving towards water-intensive farming under climate change (Kelkar, Narula, Sharma, & Chandna, 2008; Khor, 2009). Local farmers said that the quality of rice also improved and the rice could be sold at a higher price; therefore, it may help to increase the income of farmers. Organic farming is actually not new to Balinese farmers (Lansing, 2007); it has been practiced for many hundreds of years, but has not been used once in the last few decades in some subaks. Therefore, it will be easier and cheaper to implement for local farmers compared with other adaptation measures.

Some farmers mentioned that prolonged rain is associated with pest damages and some parts of Bali and Indonesia are expected to get wetter. Bali's subak system not only manages water allocation, but also synchronizes farming patterns, which will create a fallow period to kill pests in paddy fields (Lansing, 1987, 2007). This coordination will be more beneficial when the climate gets wetter in some parts of Bali and so for the rest of Indonesia. When the project team interviewed farmers in Indramayu, Java, they did not have the same synchronic farming practice. It will be interesting to explore the possibility of transferring synchronic farming practices from the subak system to other parts of Indonesia as there is evidence of its transferability (Pasaribu & Routray, 2005).

BMKG and the agriculture agency have been working with climate field school to educate farmers on how to cope with climate change (ICCTF-BMKG, 2011; Winarto, Stigter, Anantasari, & Hidayah, 2008). The climate field school will be a good place to teach farmers innovative technology and transfer good practices from other regions, as it is coordinated centrally, and focus more on 'training of local champions' unlike general extension worker programmes.

Conclusion

Most Indonesian regions have an annual rainfall of more than 2000 mm with the national annual average of about 2600 mm (KLH, 1999; Van Dijk et al., 2001). Rainfall and relatively high humidity play important roles in inhibiting climate change hazards. Vulnerability is dependent on contexts, issues, purpose, and system of vulnerability units. Therefore, this paper demonstrated how an international cooperation project identified issues, purpose, system, context, and variables to carry out vulnerability assessment in Bali/Indonesia through six steps with four methodologies.

Through the steps, the vulnerability issues were focused into paddy as the first case. The purpose and system to work for were identified as supporting local authorities to report the Presidential Decree No.5 on paddy production. Several potential hazards were also identified, which will be further investigated in a proper vulnerability assessment in the future. Drought is possibly the biggest concern among all weather-related disasters. Land use change is likely to affect the production of paddy in the context of Bali as well as other island in Indonesia (Naylor, Battisti, Vimont, Falcon, & Burke, 2007; Verburg, Veldkamp, & Bouma, 1999). Several variables affect the land use change, including water level and prices of rice and land.

These findings can already suggest to the Indonesian government and local authorities where and how adaptive measures should be implemented to handle paddy production relative to climate change. A detailed vulnerability assessment can be developed based on the issues, context, purpose, and system identified in this paper. For example, a detailed vulnerability assessment should indicate where several droughts are more likely to occur and where there is not enough adaptive capacity to cope with the droughts. For this, we may need to know climate projection, the location of irrigation system, and the level and location of extension worker programmes. Then, paddy farmers in Bali will be supported with proper adaptation measures, which will be backed up by a well-focused vulnerability assessment. This study has already shown the importance of irrigation systems. The detailed assessment will suggest to policy-makers and farmer groups the location and types of irrigation systems needed in Bali. Bali has a historical community managed irrigation system, so when a new irrigation system will be implemented on this island, it has to carefully install the new system not to conflict with the traditional system. A detailed vulnerability assessment that includes this socio and land use information as well as climate information will help the proper adaptation planning.

Disclosure statement

No potential conflict of interest was reported by the authors.

Note

1. (1) Advocate and socialize the right understanding of climate change; (2) communications strategy to raise awareness of impacts and adaptation; (3) communications strategy to use climate information (e.g. climate field school); (4) conduct impact analysis toward a seasonal shift to decide the beginning of planting season; (5) Conduct research on superior seeds that are resistant to climate change; (6) develop an agriculture, climate information system, and network, including climate field school; (7) develop innovative technology for superior adaptive variation and management of land and water; (8) development and rehabilitation of agriculture, infrastructure, e.g. irrigation network; (9) development of adaptive track husbandry; (10) empowered stakeholders, that is P3A institution, water use farmer to schedule planting; (11) form commanding post to control flooding and drought in department of agriculture; (12) improve water management in rice production; (13) increase of human resource capacity (farmers and authorities); (14) increase the minimum income of farmers through use of innovative technology and commercial commodities; (15) develop a drought early warning system; (16) increase the utilization of the drought prone map; (17) optimize alternate system in water irrigation distribution; (18) promote non-rice food sources; (19) protection of agricultural activities and its production (subsidy, agricultural insurance, tariff, and price stability); (20) regional resource analysis for sustainable agriculture development; (21) research and implement good agriculture practices; and (22) research on appropriate staple foods for local conditions.

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