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SECTORAL IMPACT AND CURRENT COPING MECHANISMS: WATER RESOURCES AND AGRICULTURE

Dampak Sektoral dan Mekanisme Penanganannya: Sumberdaya Air dan Pertanian

K. Subagyono[1] dan E. Susanti[2]

[1] *Central Java Assessment Institute for Agricultural Technology, Bukit Tegalepek Sidomulyo, Kotak Pos 101, Ungaran 50501*

[2] *Indonesian Agroclimate and Hidrology Research Institute, Jl. Tentara Pelajar 1A, Bogor 16111*

ABSTRACT

Available water resources and its quality in Indonesia have been deteriorated as an impact of climate change (and/or) environmental degradation. This could affect on farming processes particularly and agricultural development in general. Virtual available surface water gives a figure that available water decreased temporally and spatially. For instance, in Java island with cover 65% of total population only has 4.5% of the total available water in the country. Agriculture is the biggest use of water (about 70%), but it will be difficult for farmers to accomplish water requirements. Other users such as domestic (about 6%), industry (about 7%), and municipal (about 4%) are also the major users of water in the country, which may raise a conflict among the users in covering the needs. Current mechanisms to cope climate change in water resources management has been executed through adaptation and mitigation measures for supporting farming system. Integrated water resources management plays critical role in coping climate change. This includes prioritizing water requirements, water harvesting, water conservation, appropriate water allocation, and pollution control. For sustainable farming system development, mitigation strategy should also be included in the mechanism covering practices of intermittent irrigation to over come high rate of methane emission. Combining water management and tolerance crops to drought and submergence conditions is very valuable in implementing the mechanisms.

Keywords : Water resources, farming processes, adaptation, mitigation, integrated water resources management

ABSTRAK

Ketersediaan sumberdaya air di Indonesia telah mengalami degradasi dampak perubahan iklim dan atau kerusakan lingkungan. Hal ini sangat mengganggu proses usahatani pada khususnya dan pembangunan pertanian pada umumnya. Ketersediaan air permukaan secara maya berkurang menurut waktu dan ruang. Sebagai contoh, di Jawa yang dihuni 65% penduduk hanya tersedia air 4,5%. Sektor pertanian merupakan pengguna air terbesar (70%), tetapi dengan kondisi demikian petani akan kesulitan dalam memenuhi kebutuhan airnya. Pengguna lain seperti sektor domestik (6%), industri (7%), dan munisipal (4%) adalah pengguna kedua terbesar yang dapat menimbulkan konflik penggunaan air. Mekanisme yang sekarang ada dalam menghadapi perubahan iklim khususnya dalam pengelolaan sumberdaya air telah dilakukan melalui adaptasi dan mitigasi untuk mendukung pengembangan pertanian. Pengelolaan sumberdaya air secara terpadu memiliki peran yang sangat penting dalam mengantisipasi perubahan iklim. Pengelolaan ini mencakup prioritasi penggunaan air, panen air, konservasi air, alokasi air yang tepat, dan pemantauan terjadinya polusi. Untuk keberlanjutan sistem usahatani, strategi mitigasi perlu didahulukan di dalam mekanisme penerapan irigasi berselang (intermittent irrigation) untuk menghambat emisi gas metan. Perpaduan antara pengelolaan air dan penerapan variets tanaman yang toleran kekeringan dan banjir/genangan sangat strategis untuk diimplementasikan.

Kata kunci : Sumberdaya air, proses usahatani, adaptasi, mitigasi, pengelolaan sumberdaya air secara terpadu

Climate change and its variability have becoming a phenomenon of water resources and agricultural vulnerability in Indonesia since the recent decades. Impacts of climate change and its variability on water resources consist of (i) changes in rainfall/ precipitation, (ii) increase evaporation, (iii) changes in runoff and available surface flow, (iv) changes in hydrological regime, (v) sea level rise, and (vi) additional stress on scarce water supplies. Many areas of the world including Indonesia have faced water stress problems and the increase of water scarcity particularly during dry season, while flood is the worst phenomena during wet season. Figure 1 shows regions that are currently under water stress. Regions in red

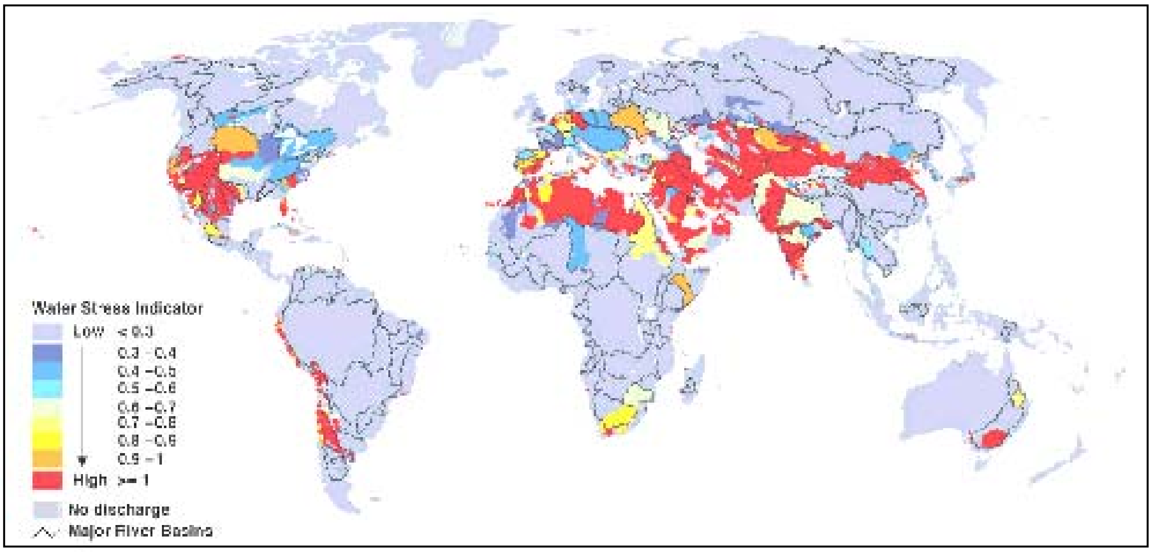

Figure 1. Regions that are currently under water stress

Source: www.undp.org/gef/adaptation/climate_change/maps/ water.htm

are currently the worst affected. Climate change is expected to increase the pressures on dwindling freshwater supplies in many regions of the world that are already under severe water stress. Refering to the map in Figure 1, Indonesia is belong to the region under low water stress as it has been indicated by the low water stress indicator, except some areas of East Java and East Nusa Tenggara (www.undp.org/gef/adaptation/climate_change/maps/water.htm). However, the virtual water data has given a figure that the available water has decreased. In Java, where the population covered 65% of total population of the country has 4.5% available water. Whereas in other areas that do not have deficit water, the availability of water is tended to decrease. Vulnerability of water resources to climate change may increase, and the water stress will be more intensive.

Inland waters in Indonesia covering areas of 534,000 km^2, consists of 394,000 km^2 swampy areas, 119,500 km^2 catchment areas and flood plains, 16,000 km^2 man-made lakes and 5,000 km^2 natural lakes. There are 521 lakes, of which fourteen (14) of them have more than 100 m depth, eight (8) lakes with more than 200 m depth, and three (3) with more than 400 m depth. The largest lakes are 1,130 km^2 wide with 590 m depth. Totally, these lakes contain 500 km^3 freshwater. As a whole, freshwater is abundant in Indonesia reaching an average annual quantity of 15,500 m^3 per capita; the availability of freshwater is quite huge, about 25 times compared to that of the world which is only about 600 m^3 per capita annually. Nonetheless, such abundance of freshwater is not evenly distributed within the country and furthermore, the availability also depends on the seasons. This condition is likely to be attributed to degradation of the environmental condition and, consequently, changes in hydrological cycle (www.un.org/esa/agenda21/natlinfo/countr/indonesa/Freshwaterindonesia04f.pdf).

Climate change and its variability have also a critical impact on agricultural productivity especially food crops. The occurrence of flood and drought is the fact which is subjected to the climate extreme. Efforts to warn the impact through the understanding of the climate variability and dynamic of extreme climate as well as strategy for handling the impact to agricultural productivity has been addressed by the government. Yet, it is felt appropriate to further the understanding and knowledge gained from the many action plans related the agricultural vulnerability to extreme climate into actual implementation of activities that would lead towards further making agriculture in the country sustainable. However, many other programs have also been implemented to come up with public awareness to promote active participation of public, planners, and policy makers in anticipating the impact of climate change within the country.

As extreme climate has frequently occurred with increase in its intensity, the pressure to water resources for agricultural production is growing. El-Nino and La-Nina respectively occurred more frequently and caused an extreme drought and flood which have negative impact on available water resources and farming processes. Boer and Subbiah (2003) reported that since 1944, some 43 droughts have occurred in Indonesia, six of which resulted from ENSO phenomena. This suggests that most of the droughts were due to the ENSO. In 1997, when a strong El-Nino occurred, 47,995 ha of drought areas of rice field were observed in Indramayu-West Java, which was much higher than that of 7,896 ha under a weak El-Nino in 2002/2003. During La-Nina, crop damage due to flood also happened, especially in areas with food crop-based cultivation. In Indramayu-West Java, it was observed that rice fields flooded during a strong La-Nina, reached an area of 50,478 ha higher than during a weak La-Nina which reached an area of 25,644 ha (Boer and Las, 2002). Boer and Kartikasari (2007) mentioned that within the period of 2003-2005, there were about 1,429 disaster incidences in Indonesia. About 53.3% were hydro-meteorological disasters. Of this figure, floods occur most often (34.1%), followed by landslides (16%), and then drought.

Those phenomena have been well understood as the global phenomena which have been controlled by the flow dynamic in the Pacific ocean (UCAR, 1994). In addition, seasonal variation has also occurred for rainfall, which is characterized by the variability in increasing and decreasing rainfall in the Indian and Pacific oceans. The change in rainfall occurs within 30 to 60 days and merely during weak El-Nino and La-Nina (Amien *et al*., 2005). Agriculture areas are often suffered by these phenomena leading to production loss.

Flood has being a natural phenomenon to which the several factors play a role especially the increase of rainfall intensity. The occurrence of high rainfall in relatively short period has lead to increase excess of rainfall leading to flood and standing water for couple of days to weeks. Its vulnerable areas to flood is also determined by the present of upstream critical watershed in which the water can not be retained but the excess of rainfall flows as surface runoff to downstream areas. It will be worth impact to food crops in the downstream areas.

Vulnerable water resources availability and crops growth to dry spell period to which the extreme climate event of El-Nino plays a role was almost annually happened. It has also been recorded that the magnitude of dry spell impact was various by sites which was due to the distinct of hydrological characteristics. Nevertheless, the magnitude of drought generally rises with time. It is felt appropriate to further anticipation into actual implementation to adapt drought variability in water resources management and food crops production system that would lead towards further making enough water and food security in the country sustainable.

A phenomenon of season break had been lead farmers to felt their crops. Lag of rainfall during rainy season has often been unpredictable and most farmers have felt in their anticipation. Farmers started their crops at least twice event of rainfall occurred and they assume that rainy season has just started. After they start their crops, rain has just stopped for two weeks to one month and their crops will not be survived. If they start again after they felt their first crops, it will be some delay in the second crops during dry season. The impact of drought during season break is normally less than that due to decrease of rainfall far below normal rainfall. Rainfall during dry season is low and it is far to cover crops water requirement. Drought is not only occurred in rainfed rice areas but also in irrigated rice areas especially in the tail area of irrigation channel.

Vulnerability to climate change is not only subject to biophysical means but also social and economic conditions. Fischer *et al*. (2002) have illustrated the world social vulnerability. Many factors contribute to social vulnerability, such as rapid population growth, poverty and hunger, poor health, low levels of education, gender inequality, fragile and hazardous location, and lack of access to resources and services, including knowledge and technological means. And when people are socially disadvantaged or lack political voice, this vulnerability is exacerbated further. Indonesia belongs to the country with relatively high rate in population growth. This high rate of growth and agriculture's crucial role in overall rural development mean that in the initial stages this sector will have to absorb many of the new entrants into the rural labor force. Currently half of the world's workforce is employed in agriculture, and the sector dominates the economies of 25% of the world's countries.

A limitation of baseline data of drought and flood affected areas particularly and water resources in general is also a constraint to have a focus program of adaptation and mitigation. In Indonesia, only few areas in the country have a baseline data in term of drought and flood affected areas as well as available water resources. This is the reason why the effect of drought and flood on available water resources status and agricultural areas has not been handled properly and the available water resources and agricultural areas are still very vulnerable. The baseline study of drought and flood affected areas and available water resources is urgently to be conducted to perform baseline data for adaptation and mitigation actions.

IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES

Deterioration of available water resources increases in the recent decades leading to shortage water for agriculture, domestic, municipal and industry. Impact of climate change on water resources can be addressed to surface and sub-surface water. The changes in rainfall pattern and its intensity affected on recharge water capacity to the ground leading to reduce inflow to groundwater body. Since in many catchments area rainfall water is much converted into runoff flowing down to the river due to deterioration of watershed river flow is getting bigger and bigger. Flow magnitude has becoming bigger but quality of river water is deteriorated due to high sediment concentration as an impact of increasing erosion rate. Change in surface and groundwater, water quality as well as water availability and demand are described.

Figure 2 shows maximum and minimum river flow caused by flood and drought in Indonesia. The information was gain from 52 rivers in Indonesia showing various flows during flood and drought events. The fact that dynamic behavior of river flow during extreme climate change is obvious, especially during 90s era and become more obvious at the recent years. Before 70s, there was almost no change in maximum and minimum river flows, then started to change after 70s with more obvious after 90s era (Figure 2). In addition, rainfall intensity tends to increase in the last decade, especially during wet season causing high river flow. Change in rainfall intensity and its pattern is subject to which the surface water has changed.

Change of the potential of surface water has been observed in many reservoirs in Indonesia. It was obviously identified that volume of water can be stored in the reservoir has changed relative to the planned water volume during construction of the reservoir. Difference between planned water volume and observed water volume suggests that most of the volume of water in the reservoirs has already depleted (Figure 3). Perum Jasa Tirta (PJT) II has recorded during more than 20 years except Wonorejo (East Java), Batutegi (Lampung), Bili-bili (South Sulawesi), and Sermo (DI Yogyakarta). The reason is that high sedimentation has already deteriorated the reservoir capacity. The change in rainfall intensity, in many cases tend to increase, is a subject to high erosion rate and sedimentation into the reservoir.

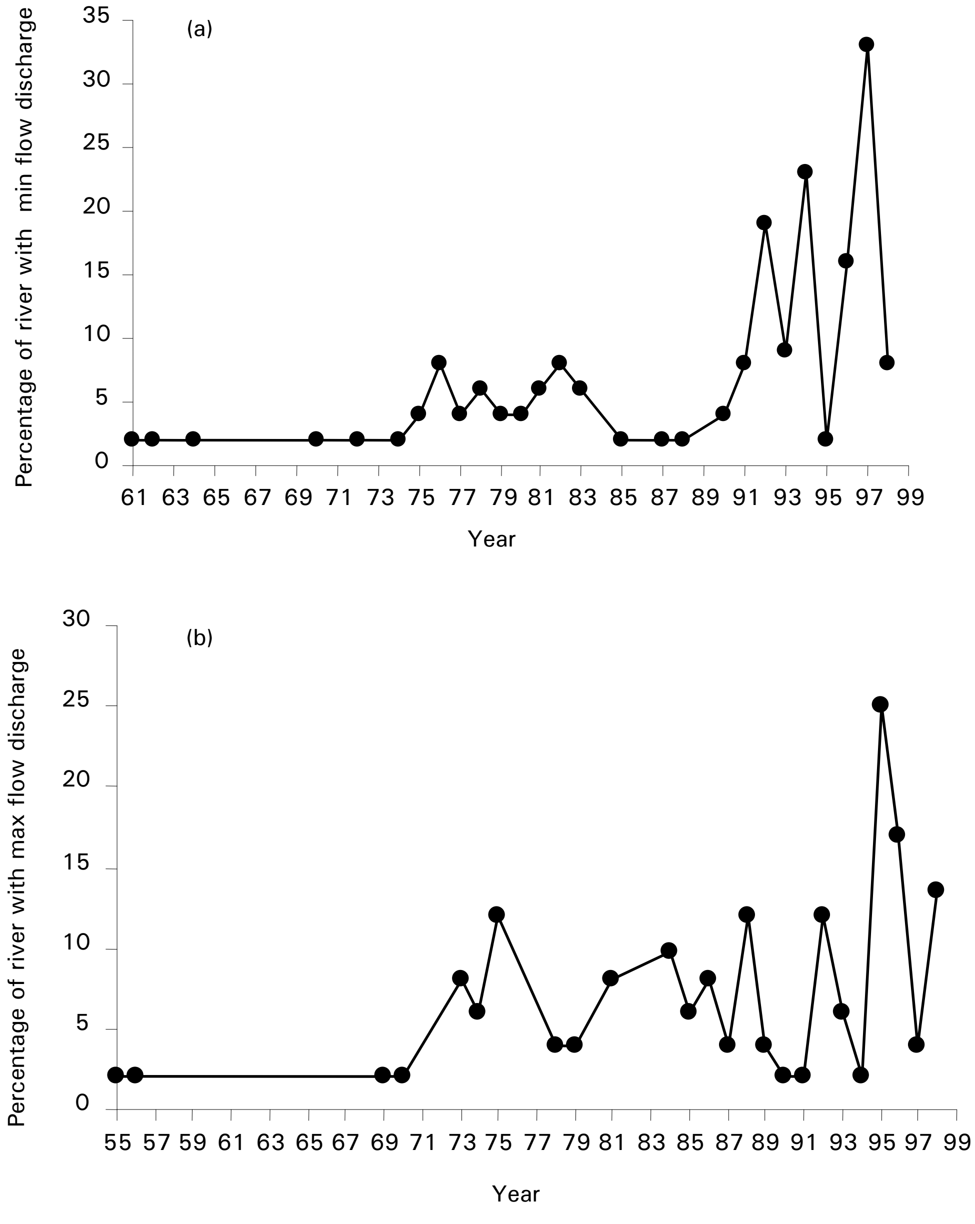

Figure 2. Percentage of river with (a) minimum and (b) maximum flow causing potential drought and flood

Source: Adapted from Loebis (2001)

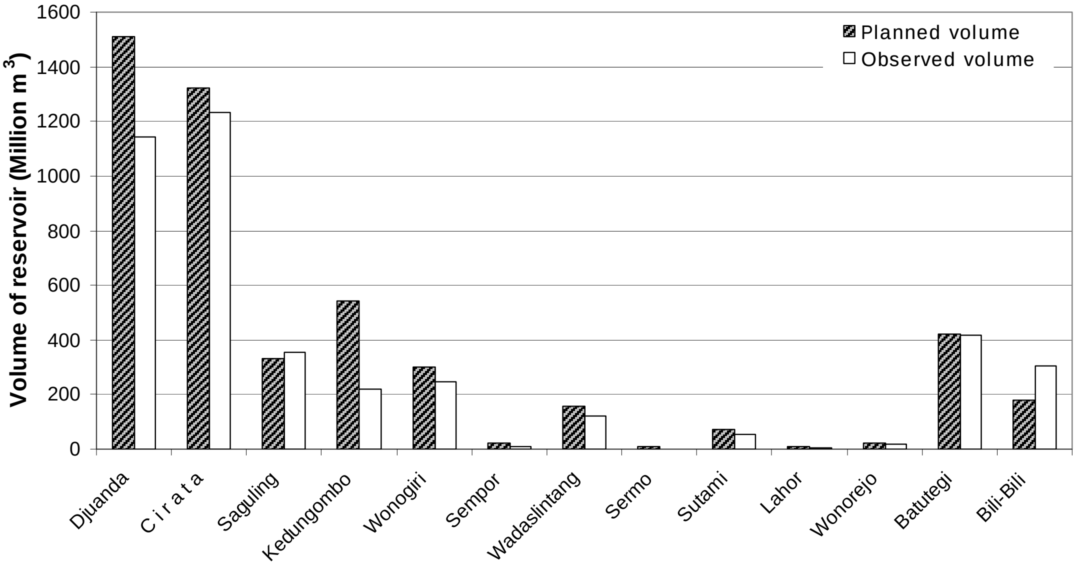

Figure 3. Change of available water in the main reservoirs in Indonesia

Source: Data adopted from NEDECO (1998)

Impact of extreme climate on water storage capacity is also a critical phenomenon. During La-Nina event, rainfall amount is relatively high recharging the reservoir with higher volume relative to the normal volume water capacity. Effect of extreme climate on water storage capacity is depicted in Figure 4. Comparing two extreme climate of La-Nina and El-Nino events and the effect on water storage capacity, it is obvious that water storage capacity higher during La-Nina event rather than that during El-Nino event.

It was reported that the total water demand of the country was 1,074 m^3/sec which is used for irrigation, domestic, municipal and industrial purposes, while the low flow available at the normal climatic year is only about 790 m^3/sec (Anonim, 2003). This explains that there was an unbalance between water demands and the potential water availability, particularly during the year of scarcity. Virtual water available (Figure 5) described clearly that in Java island where the population cover 65% of the total population of country only able to cover 4.5% of available water. In Sulawesi, it is predicted that the available water will be deficit in 2015. In other islands, although the available water is still surplus but the availability decreases by time (Sjarief, 2003).

CURRENT MECHANISMS IN COPING WITH CLIMATE CHANGE IN WATER RESOURCES AND ITS MANAGEMENT

Adaptation mechanisms could be implemented for sustainable water resources use, which may focus on short and long-term response strategies. Short and long term strategies include technologies for controlling water use and improvements of water-management practices. The adaptation measures consist of (i) water harvesting, (ii) water conservation, (iii) groundwater recharge through improvement infiltration capacity, (iv) overcoming high evaporation, (v) efficient water use, (vi) improvement of water holding capacity of soil, (vii) restoring and conserving river channel, and (viii) reduce water pollution. These measurement could integrate in watershed management to improve hydrological function. Beside the physical measurement, regulations and institutions could also be part of adaptation to sustain available water resources and its management. Appropriate technologies are needed for adaptation.

As far as water scarcity and increased demand of water are concerned, water resources

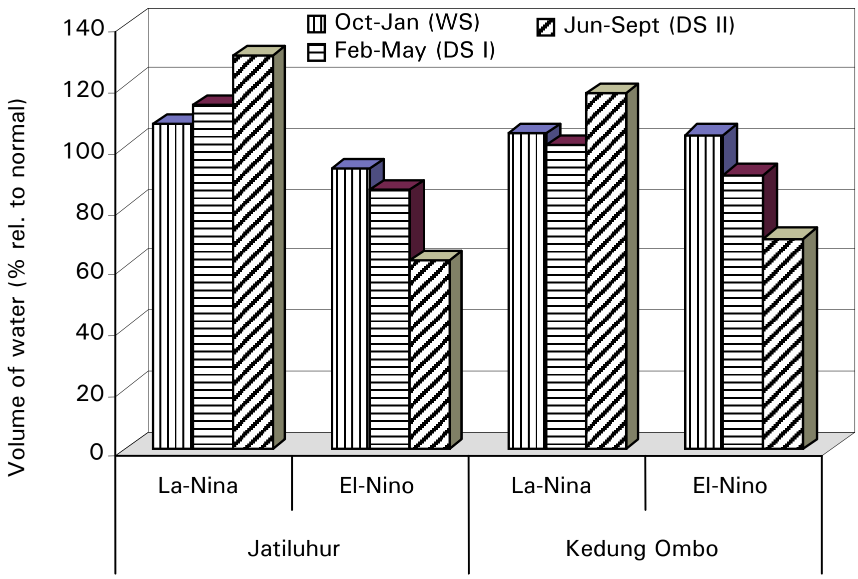

Figure 4. Effect of extreme climate on volume of water in two big water reservoirs in west and central java

Source: Las *et al*. (1999)

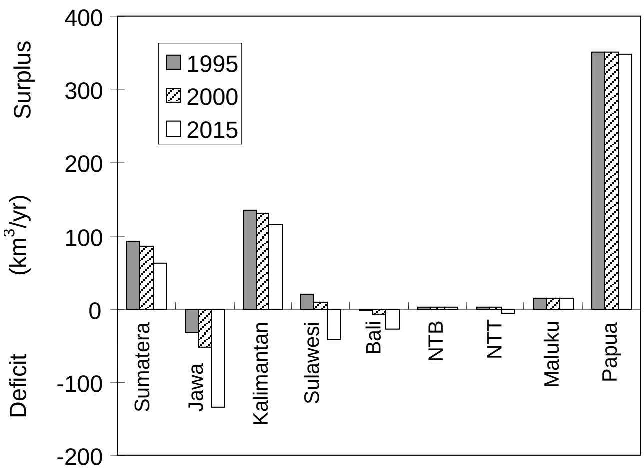

Figure 5. Virtual available water in Indonesia

Source: Sjarief (2003)

management plays a critical role. Balance between available water resources and demand of water is used as a principle management. As the water demand has increased for various used of agriculture, domestic, municipal, and industry, the water resources in the country felt upon the pressure. In addition, the available water has become scarcity as climate change and deterioration of environment occurred. Water resources management is, then, addressed and focus to four critical strategies, i.e. (i) prioritize the need of water, (ii) appropriate water allocation, (iii) water conservation and water harvesting, and (iv) pollution control with aimed to reach community welfare. The water resources management for sustainable use is summarized and depicted in Figure 6.

The water requirement has increasing since last decade particularly for agriculture, domestic, industry and municipal, while the availability of water has becoming limited. The availability of water is determined by dynamic of hydrological cycle, which has affected by two major factors of climate change and deterioration of environment particularly in catchments areas. To come up with sustainable use of water resources, an integrated water resources management needs to be executed. Prioritizing water use is addressed to accomplish domestic and agriculture water uses with correct proportion. As far as unbalance between demand and available water resources is concerned, the use of water resources should be based on proportional water sharing among the users.

Appropriate water allocation is also a basic strategy to be implemented to come up with effective and efficient use of water. The fact that rainfall distribution is temporally varies, particularly between wet and dry seasons, and the water holding capacity of soil decrease due to lower organic matter content, water conservation is becoming critical. During dry spell period, available water is very limited and farming processes are hampered by the water scarcity. This is the reason why water harvesting is needed for optimizing crops intensity and sustainable farming processes. It is not rare that irrigation water for crops production is polluted either from pesticide and an industrial waste. Pollution control is urgently to be implemented to achieve good quality water for irrigation.

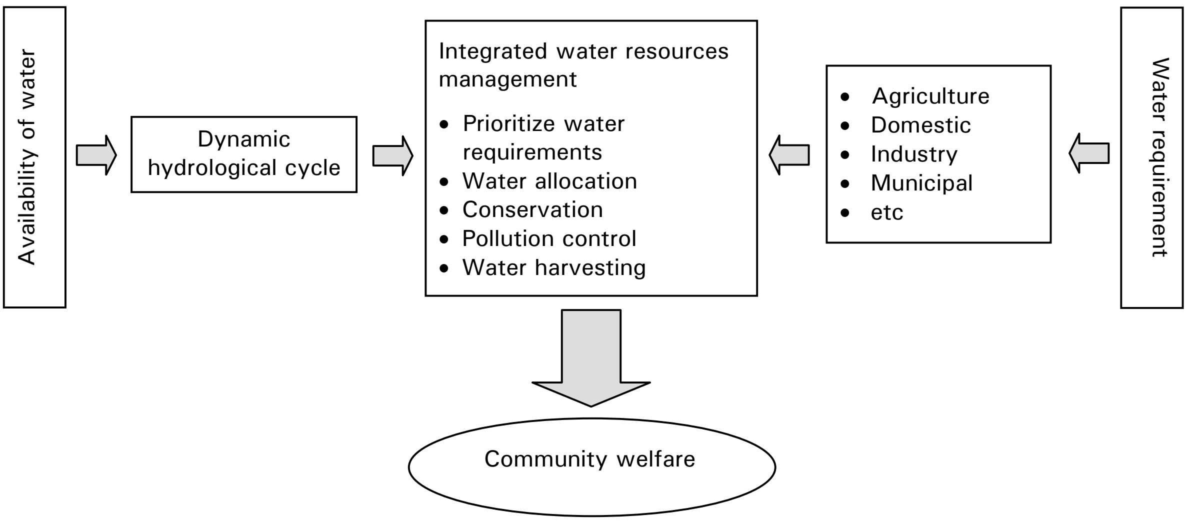

Figure 6. Water resources management for sustainable use

Source: Wignyosukarto with modification (unpublished)

MITIGATION AND ADAPTATION FOR SUSTAINABLE AGRICULTURE

Available water resources are crucial for sustainable farming processes. It is not only for supporting crops, livestock and fisheries production but also for climate change anticipation through mitigation and adaptation mechanisms.

Mitigation

Mitigation efforts to reduce impact of climate change are urgent and should be integrated with adaptation activities. Several strategies of mitigation have been introducing through (a) water management, (b) low emission crop varieties, and (c) integrated crops-livestock management. Each strategy can be implemented considering local farming-specific.

It is urgent to facilitate farmers in implementing a water-management system for their rice fields. In general, farmers prefer to maintain standing water in the field as high as 20 cm with very limit to drain water, after a period of 2-4 weeks. This leads to a condition that a rice field produces much CH_4. Whereas, intermittent irrigation provides an aerobic condition where oxidation processes occur. Setyanto *et al.* (1997) reported that intermittent irrigation (intermittent flooded) reduced methane (CH_4) emission by 82.5% compared to continuously flooded (Table 1).

Table 1. Effect of water regime on methane emission in Pati, Central Java

Water regime	CH_4 emission	Changes in CH_4 emission
	kg/ha	%[1]
Continuously flooded	142.6	
Intermittently flooded	25	-82.5
Saturated unflooded	78.8	-44.7

[1] As compared to continuously flooded system
Source: Setyanto *et al.* (1997)

Introducing crop varieties is also an option to be presented to farmers. Crop selection and breeding seem to be alternatives to less emission crops varieties. Research institutes such as the Indonesian Center for Rice Research are becoming very important in providing new rice varieties with less emission. Developing rain-fed rice may also be possible to reduce CH_4 emissions, and intermittent irrigation can reduce by 50-60% of CH_4 emissions from rice fields (Setyanto *et al.*, 2003).

Integrated crops-livestock management is another strategy which may contribute to reduced emissions. Manure is converted into compost for fertilizer and fresh manure, which may not emit greenhouse gases such as CH_4. It may also be converted into bio-gas to produce energy for electricity, gas stove for cooking and other purposes which may help farmers.

Adaptation

A lot of efforts have been experienced in adaptation mechanism in agricultural sector either through water resources management or crops-livestock managements. Adaptation to climate change is the strategy by which an agricultural production system should be directed to apply to drought, flood (submergence), temperature increase and to some extend to sea level raise and salinity.

Climate change has often made the agricultural production system vulnerable to drought. In order to sustain the growth and production of crops, adaptation to drought has been directed to improve the water availability during dry spells. The paucity of available water leads to unfavorable growth of cultivated crops especially in a seasonal-based cropping system. Efforts to provide more water have been made through many strategies, including a water harvesting system using channel reservoirs and mini water-pond, combined with efficient water use through applied irrigation.

The water-harvesting capacity of a channel reservoir depends on its dimensions and the characteristics of the stream where it is constructed. Roughly, the gross potential of water available in the channel reservoir can be calculated through the catchment areas and the annual rainfall. Crop varieties, tolerant to drought, have also been introduced to farmers to adapt to drought during dry-spells.

Flood protection in agricultural areas has been conducted to reduce crop submergence and loss of yields. Downstream agricultural areas especially in coastal regions have to be protected from coastal flood hazards. This can also be conducted through the introduction of a reservoir channel. Adaptation of crop growth and production to submerged hazards has been done through the introduction of crop varieties, resistant to submerged conditions.

To adapt climatic uncertainty, arrangement of crop time tables is very urgent and should be combined with the prediction of the favorable time for planting as well as the amount of available water. Best planting time was becoming a question for farmers to start their crops in many areas in the country. As many have experienced in the country, planting times between places differ, due to climate extreme. For example, the initial planting time is earlier than normal during a La-Nina year and later than normal during an El-Nino year.

To anticipate the future climate condition concerning to appropriate agricultural planning and to avoid failure in harvesting the crops, climate prediction needs to be established. Many models of climate prediction have been created by various national and international institutions. The one that has been used and developed by the Indonesian Agency for Agricultural Research and Development (IAARD), through the Indonesian Agroclimate and Hydrology Research Institute, is the Kalman Filter model.

Since the climate in the country varies spatially and temporally, the accuracy of the model used also varies. Its accuracy also differs by the length of the period to be predicted. As it was shown in the validation process, the model is accurate for a short period (3 months) compared to the longer period (6 or 12 months). Therefore it is urgently needed to modify climate prediction models based on local specific conditions.

As far as the climate data are concerned, there is a gap of available data outside Java, since the weather station is relatively less dense compared to those over Java. Therefore, there is a need to develop weather-station networks outside Java and concurrently to maintain the stations in Java, especially in the central areas of food-crop plantations. Integration among the institutes, having the task to record climate data-such as BMG, the Ministry of Public Works and the Ministry of Agriculture-will be a focus of the climate-station network program.

It can be summarized that options to adapt food production processes to climate change and to secure available food are: (a) integrated crop management, and (b) water resources management. Priority of technologies for integrated crops management are: (a) appropriate cropping calendar, (b) introducing crops varieties tolerant to drought and flood and early mature crop varieties as well as dry seedling technology. Priority of water resources management technologies are: (a) water conservation technology, (b) water harvesting technology, (c) technology of modification of micro climate, (d) technology of efficient water use, and (e) intermittent irrigation for rice field. Water conservation technologies should be directed to increase infiltration and groundwater recharge and to reduce evaporation as well as to increase moisture content. Water harvesting technologies are addressed to collect water in the wet season and to use water especially in dry season. Micro-climate modification needs technologies of crops diversification. It should be an integration of water harvesting and irrigation application. Technologies of efficient water use are addressed for efficient irrigation. The intermittent irrigation technology is needed to reduce methane emissions from rice fields and increase the efficiency of water use. The technology for adaptation and mitigation is presented in Table 2.

Table 2. Technologies priority for mitigation and adaptation to climate change

Agriculture sub-sector	Climate prediction	Adaptation technology	Mitigation technology
Rice field/ horticulture	a. Climate database management b. Climate information technology c. Climate model development	a. Crops tolerant to drought and flood b. Early mature crops varieties c. Cropping calendar d. Water harvesting e. Water conservation f. Efficient irrigation	a. Low emission crops varieties b. Appropriate fertilizing c. No tillage/minimum tillage d. Intermittent irrigation
Perennial crops	a. Climate database management b. Climate information technology c. Climate model development	a. Introducing estate crops varieties tolerant to drought and flood b. Appropriate crop sheltering c. Correct planting distance d. Optimum crops density	a. Low emission crops varieties b. Appropriate fertilizing c. No tillage d. Appropriate slash and burn e. Bio-fuel
Livestock	a. Climate database management b. Climate information technology c. Climate model development	a. Adaptable cattle to dry and wet climate b. Communal livestock sheltering	a. Composting manure b. Biogas production
Peat land	a. Climate database management b. Climate information technology c. Climate model development	a. Minimum tillage b. Balance fertilizing c. Appropriate soil amelioration d. Drainage control e. Subsidence control	a. Overcoming slash and burn b. Avoiding over drain c. Maintaining soil moisture

Source: Subagyono *et al*. (2009)

CONCLUSIONS

1. In Indonesia, available water resources have been depleted prior to the impact of climate change and deterioration of environmental condition particularly in watershed areas. Impact of extreme climate including El-Nino and La-Nina which raised phenomena of drought and flood is the major impact of climate change. Rainfall variability and its distribution where high intensity occurred during wet season and severe dry spell occurred during dry season are the worst impact on farming processes particularly and agriculture in general.
2. Current mechanisms in coping climate change in water resources has been executed through adaptation practices focusing on integrated water resources management such as water harvesting, water conservation, water allocation, prioritize water requirements, and pollution control. In view point of the use water resources for farming processes, appropriate water management with principal on optimizing water harvesting and conservation as well as efficient water uses for irrigation is a critical strategy.
3. As far as farming sustainability is concerned, mitigation and adaptation through water resources management are the critical mechanisms. Intermittent irrigation for rice field and introducing low emission rice varieties are important mitigation measures, while water harvesting and efficient water use in combined with crops tolerance to drought and submergence and early mature crops varieties are priority for adaptation.

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