Climate change impacts on availability and vulnerability of Indonesia water resources

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Abstract. Global climate change has been recognized as a challenging issue in the past decades and with significant impacts on many aspects of human life, especially on the availability and vulnerability on water resources. Food production requires a large portion of water demands and directly related to population that is still increasing in Indonesia. Therefore food production will have direct impacts on land and water resources with great implications on environmental degradation. Water resources development and management in Indonesia under stress in changing climate is considered still in low risk of water scarcity nationally with space-time variation, such as for Java Island and many developing urban areas already at high water stress level. Sustainability of water resources in such areas could be achieved only through trade-off and balancing the competing water demands and available supply, satisfying the law of mass conservation as a sufficiency condition. These high-risk water stress areas would need development of water storage and irrigation infrastructures and adoption of crop-water productivity strategy to improve water use efficiency for food and agricultural production and ensure water and food security of the country.

1. Introduction and a brief summary
Climate change has become a very serious global issue in the past decades and certainly would have significant impacts on availability and vulnerability on water resources in Indonesia through water supply and demand. Food production requires a large portion of water demands and directly related to population that is still increasing in Indonesia. Therefore food production will have direct impacts on land and water resources that trigger encroachment to the upstream areas with great implications on environmental degradation. Doos and Shaw [1] had tempted to assess the sensitivity of food production to various aspects of global change and environmental degradation during the next few decades and concluded that one cannot say with any certainty whether or not food supply will meet expected demand in 2025, especially in Less Developed Countries, and bringing into use 10% of available potential cropland would make little difference. Sheffield et al. [2] found that the previously reported increase in global drought is overestimated because the Palmer Drought Severity Index (PDSI) uses a simplified model of potential evaporation that responds only to changes in temperature and thus responds incorrectly to global warming in recent decades, and suggested that there has been little change in droughts over the past 60 years.

Increased pollutions from agricultural practices, domestic and industrial wastes as indicated from water quality parameters that intensify water demands, reduced water availability and increased vulnerability and uncertainties in global climate change has intensified water-related disasters such as
extreme weather with floods and droughts, in frequency and magnitude, in addition to direct impact of land use changes, as river basin response, storm runoff and modified river terrain geomorphometry. Recent hydrologic and water resources events in Java Island, and Indonesia at large, were characterized by occurrences of extreme floods and droughts with high sediment/pollutant contents in the water bodies, and water crisis is anticipated as a real threat to satisfy ever-increasing water demands due to increased population pressures. Java Island with 121 million people in 2000 and extensive land conversion activities has a dire situation in the coming future. Changes were also recognized to watershed functions due to intensive agricultural practices and industrial development. Conversion of paddy fields alone in Java was estimated at 26 thousand hectares per year in the past decades, but some believed this figure could be a few times larger, indicating obvious uncertainties. Significant impacts of these land use changes and environmental degradation are now believed to have changed the natural carbon, nutrient and water cycles, i.e. the ecological hazards [3]. Pawitan [4] reported that Java rainfall tends to decrease compared to earlier last century, especially during dry seasons that were getting longer, while rainy seasons varies spatially with some areas show lower annual rainfall. The trend in seasonal rainfall changes implied a proportional reduction in monthly discharge for major rivers in Java at rates between +0,8 and -8,3% by 2030 and between +1,3 and -13,8% by 2050. Evidence of significant decline of rainfall has threatened Indonesia water resources due to depletion of forest resources and global climate change [5].

The present paper attempts to discuss the challenge of global climate change and its impacts on Indonesia water resources that are suggested should be based on evidence-based scientific knowledge to avoid speculative knowledge as found in myths. Brief descriptions of Indonesia water resources availability be given and then vulnerability issues will be discussed as consequences of ever-increasing water demands of the limited availability of water resources. Notion of sustainability of water resources in terms of water security and water scarcity measure within acceptable risk of policy failures, also to be presented for the case of Citarum river basin showing supply-demand analysis to determine its carrying capacity ensuring satisfaction of the law of mass conservation. Finally, some national programs related to water resources and current infrastructure development are given as an illustration of management and conservation efforts are mentioned.

2. The challenge of global climate change

Indonesia has a long history of climate measurements along with the development of agriculture in Java Island and some other regions in Indonesia during the Dutch colonial era in the 19th Century. It becomes obvious that abrupt climate change has socio-political significance and this could be recognized also with regime changes as could be indicated that occurred in Indonesia to the New Order in the mid-1960s and then to Reformation Order in 1998 following severe 1997 El Nino event. Therefore, the challenge of global climate change would be of interests to those in power and a way to anticipate and mitigate it needs to be ensured for the socio-political stability of a regime. Presently, the UNFCCC has imposed the precautionary principle with no regret policy in promoting actions plan for climate change adaptation and mitigation, while what we need is policy based more of an evidence-based scientific knowledge to avoid relying on speculative knowledge as in myths. Scientific evidence can be found only from empirical observations as being conducted through setting up a network of Global Atmospheric Watch (GAW) with the primary mission to describe the atmospheric chemistry, and one such GAW station is the GAW Bukit Koto Tabang in Indonesia, where some CO2 measurements during 2004-2013 will be presented next just to indicate the lower rate of increasing CO2 concentration at the site that represents tropical region like Indonesia.

To understand the essence of climate and climate change, it is good to learn again the quotations given by James R. Fleming, a historian of science and technology, in his citation published in Physics Today - March 2009 on Brian Fagan book 2008: ‘The Global warming: the rise and falls of civilizations’. First, quoted from meteorologist and mathematician Edward Lorenz who once reminded us that:

“climate is what you expect; weather is what you get”

And second might add a quotation from Brian Fagan on his book mentioned above that:
“climate change is what you expect; social and economic collapse leading to violence and massive suffering is what you may expect to get – even with the best planning”

3. **In situ CO₂ measurements at GAW Bukit Koto Tabang Station in Indonesia**

The mission of Global Atmospheric Watch (GAW), taking into account the Integrated Global Atmospheric Chemistry Observations strategy [6], is to

- Reduce environmental risks to society and meet the requirements of environmental conventions.
- Strengthen capabilities to predict climate, weather and air quality.
- Contribute to scientific assessments in support of environmental policy.

Through a programme of

- Maintaining and applying global, long-term observations of the chemical composition and selected physical characteristics of the atmosphere.
- Emphasizing quality assurance and quality control.
- Delivering integrated products and services of relevance to users.

Figure 1 shows CO₂ measurements, 2004-2013, at the Global Atmospheric Watch (GAW) Station at Bukit Koto Tabang (BKT), West Sumatra-Indonesia in comparison to observations at Mauna Loa Station and the Global average [7]. Apparently, the CO₂ concentration at GAW BKT is consistently lower than the Global average emission with increasing rate at 2.67 ppm year⁻¹. It could be estimated that at GAW BKT site, the CO₂ concentration will reach 400 ppm level around the year 2020, while globally 400 ppm level was already reached in 2012. Need to be watched the spiking increase of CO₂ concentration just before 2013 if it of any significant and to pay special attention to condition during 2015 El Nino with massive haze from wildland and forest fires.

![CO₂ trend rate at GAW = 2.67 ppm year⁻¹](image)

**Figure 1.** GAW CO₂ measurements as compared to that at Mauna Loa and Global

4. **Indonesia water resources conditions and availability**

As a flowing resource, water availability could be recognized from its existence on and as a feature of land resources. Here water availability quantitatively is to be recognized in land and forest resources and as a component of water resources systems and the knowledge underlying it. In these way Indonesia Water Resources conditions and availability can briefly be described as follows:

- Land resources: 1.91 Mkm² with 17 000 islands (1.3% of world’s land surface) that contains 10% of world’s plant species, 12% of mammal species, 16% of reptiles and amphibians, and 17% of bird species; land use and cover changes;
- Forest resources as dominant part of land resources: 144 Mha (~74%) with 109 Mha forest cover; 18.8 Mha conservation forests; 30.3 Mha protection forests; 64.4 Mha production forests; 30.5 Mha conversion forests; Deforestation rate: 0.3 Mha yr⁻¹ in 1970’s to 3.8 Mha yr⁻¹ in 2000, but stable out at about 1.0 Mha yr⁻¹ at present;
- Water resources systems: components of runoff cycles represent a simple water balance on land surface;
- Watershed Environment resources: air, water, wetlands, wildlife, aesthetics, as well as toxic & hazardous wastes. Some consequences such as increase GHG, global warming, sea level rise; and
- Knowledge resources: Science and Technology, including local/traditional wisdom.

The status of Indonesia water resources can be examined from primary water availability by major islands as given in Table 1, indicating a total water available of 2,110 mm year⁻¹ or equivalent to 127,775 m³ s⁻¹ that is equivalent to four million MCM/year (MCM= mega cubic meter), and with reference to Dai and Trenberth [8], approximately represents 10% of global continental discharge of freshwater. Dividing this regional water availability by the population of the region based on 2010 population census give water availability index for Indonesia that ranges from 50 m³ person⁻¹ year⁻¹ for metropolitan areas like Jakarta to about 500,000 m³ person⁻¹ year⁻¹ for West Papua or approximately 18,000 m³ person⁻¹ year⁻¹ for the national average. This primary water availability is relatively abundant compared to WHO standard water demand at 1,000-2,000 m³ person⁻¹ year⁻¹, however un-equal distribution in time and space as natural constraints in many cases has caused serious problems of water scarcity to the environment and society. Monsoon rains drop 80% of the annual total during the rainy season, and severe droughts with widespread impacts occur almost periodically associated with ENSO phenomena. The typical seasonal pattern of rainfall climatology in Indonesia can be recognized in three rainfall types as monsoonal and local types already well studied from historical data measurements. The characteristics of Java major river basins and their stream flows are as given in Table 2 below.

Hydrologic characteristics of these major rivers, as presented in Table 2, show strong seasonal variations with ratios of maximum discharge to minimum discharge 20 to well over 100, and it is recognized that these ratios are increasing almost for all major rivers in Java due to land use and cover changes and likely climate change. These increasing trends are characterized by increased maximum discharges and lowered minimum discharges. Therefore, indicating the deterioration of water storage capacity of the basins, naturally on the natural water bodies such as lakes with disappearing small lakes, as well as on reservoirs and dams.

| Island   | Area (10³ km²) | Rainfall (mm yr⁻¹) | Runoff (m³ s⁻¹) | Groundwater (m³ s⁻¹) | Total Water Available (m³ s⁻¹) |
|----------|----------------|--------------------|-----------------|----------------------|-------------------------------|
| Sumatra  | 477.4          | 2,801              | 1,848           | 27,962               | 212,128                       |
| Java     | 121.3          | 2,555              | 1,658           | 6,378                | 71,915                        |
| Bali&NT  | 87.9           | 1,695              | 997             | 2,779                | 31,251                        |
| Kalimantan | 534.8       | 2,956              | 1,968           | 33,359               | 283,699                       |
| Sulawesi | 190.4          | 2,156              | 1,352           | 8,157                | 49,758                        |
| Maluku   | 85.4           | 2,218              | 1,400           | 3,785                | 43,858                        |
| W. Papua | 413.9          | 3,224              | 2,175           | 28,524               | 32,754                        |
| Indonesia| 1,911.1        | 2,779              | 1,832           | 110,944              | 127,775                       |

Source: Pawitan et al. (1996)[9]

Regional characteristics of Java water resources can be shown from values of specific discharge \( Q_{\text{max}}/A \) of the rivers, ranging from 15 m³ s⁻¹ 100km⁻² to 80 m³ s⁻¹ 100km⁻², but mostly under 30 m³ s⁻¹ 100km⁻² except for Serayu and Ciujung. This high flow characteristic of Java major rivers relatively mild compared to many rivers worldwide. It is believed that at present conditions, these specific discharges of Java’s major rivers are somewhat lower than those historic conditions, while seasonal flow
patterns of these seven rivers from daily discharge data at major hydrometric stations indicate flashy floods for most rivers, except for Cimanuk at Monjot and Citanduy at Petaruman stations.

**Table 2.** Hydrologic characteristics of some Indonesia major rivers

| No. | Name of River | Station | Catchment area (A) (km²) | Q (m³ s⁻¹) | Qmax (m³ s⁻¹) | Qmin (m³ s⁻¹) | Qmax/A (m³ s⁻¹ 100km⁻²) |
|-----|---------------|---------|--------------------------|------------|---------------|---------------|------------------------|
| 1   | Citarum       | Nanjung | 1,675                    | 68.7       | 455.0         | 5.4           | 27.1                   |
| 2   | Cimanuk       | Rentang | 3,003                    | 134.7      | 305.6         | 19.9          | 14.6                   |
| 3   | Citanduy      | Cikawung | 2,515                    | 204.0      | 710.6         | 16.3          | 39.2                   |
| 4   | Serayu        | Rawalo  | 2,631                    | 273.4      | 1,497.0       | 58.8          | 76.8                   |
| 5   | Progo         | Bantar  | 2,008                    | 89.3       | 596.0         | 9.0           | 29.8                   |
| 6   | Bengawan Solo | Bojonegoro | 12,804                  | 362.9      | 2,127.0       | 19.0          | 17.0                   |
| 7   | Brantas       | Jabon   | 8,650                    | 258.7      | 866.1         | 46.6          | 10.0                   |

Source: Catalogue of Rivers, Vol. 1,2,3,4,5. [10]

5. **Necessary measure of water resources availability**

Water resources availability as the quantity of water given in Table 1 could be misleading. More fundamentally, measure of water availability should not be set only based on the quantity of water in reservoirs or streams as blue water, however need to consider to acceptable levels of environmental health in terms of green water and grey water that also represent water quality problems. Watson et al. [11] presented a good discussion taking into account the water quality issues in determining water availability and presented in map form based on turbidity information.

Taking into account the availability of water resources to satisfy all the needs for human consumption as well as for environmental health has been known in the concept of water footprint that provides means to estimate carrying capacity of a region in providing necessary consumption and production of goods and services of the region.

The basic principle to estimate carrying capacity of a region that needs to be satisfied to guarantee sustainability of water resources can be expressed by simple hydrologic budget balancing the supply and demand for water of the region as to be illustrated later in the case of Citarum river basin.

6. **Key issues on water security challenges in Indonesia – the Anthropocene Epoch**

Anthropogenic influences as could be witnessed in Java Island, in the past century - land use and cover changes from forest cover to agricultural uses, but in more recent decades land use conversion is dominated from agricultural to non-agricultural uses such as for human settlement and industrial uses, including infrastructures. With the very likely influence of anthropogenic activities to the global warming that causes the global climate change has been recognized as the Anthropocene epoch in geologic time.

The Boeke Report, 1941 [12] titled: ‘from four million to forty million in Java and Madura’ reported that Java population density increased from 35 person km⁻² (1815) to 330 (1930) with distribution quite diverse from 9 to 880 person km⁻² (1815). Recent population density in Java had increased to 1000 (2000) with population distribution ranged from 100 to 10,000 person km⁻². This population distribution should always be considered in regional spatial planning and development. Population pressure to land resources had increased storm runoff and modified river terrain geomorphometry. Changes in river basin response system with more intense flooding in frequency and magnitude, as a direct impact of land use changes, not to mention the impact of climate change. Next are five key issues related to water security challenges due to population pressure with intensive agriculture and recent rapid industrial development implied extensive land use changes (land conversion) and increased water demand, water quality deterioration, and suspected to cause long-term changes, in addition to global climate change, make the water environment under stress:
• Increased pollutions from agricultural practices, domestic and industrial wastes as indicated from water quality parameters that intensify water demands. Sedimentation, water pollution and Eutrophication: land use changes from forest cover to agriculture and then to other uses already make a common pattern of development.

• Deforestation rate averaged at one million ha year\(^{-1}\) in the last three decades, that reached three million ha year\(^{-1}\) at the turn of the century with a change of regime, but presently well below one million ha year\(^{-1}\), while reforestation rates only targeted around 500,000 ha year\(^{-1}\) due to the very high costs. The balance between reforestation and deforestation rates should be a common norm of spatial evaluation.

• Water environment under stress in changing climate: environmental degradations, water, climate and anthropogenic-related disasters (droughts, floods, pollutions, groundwater problems, forest fires, land subsidence).

• Water security: water supply (quantity, quality, continuity and availability), water access, water quality, and wastewater treatment. Water Infrastructure Investments: dams (50 dams in Indonesia in 5 years from 2015-2020), public water supply for food and energy security (cities), renewable energy, water transportation.

• Governance and regulation: coordination between stakeholders (academicians, government, corporations and communities), river basin integrated management (upstream and downstream), groundwater management, Integrated coastal development and management;

The recent condition of Indonesia Forest Resources (interpretation from Landsat images)

• Degraded forest land is 59.62 million ha.
• Deforestation rate is 1.09 million ha /annum (2000-2006).

Natural forests in Java have declined substantially in the last decade:

- 10 million ha (1800an)
- 1 million ha (1989)
- 0.4 million ha (2005)

Degradation was severe and un-controllable especially during reformation/autonomous era, as the permit was not acknowledged, illegal logging, forest encroachment and conversion to other uses. Margono [13] reported that 38% (6 Mha of 15.7 Mha) of gross forest loss in Indonesia 2000-2012 occurred within primary forest cover (natural forest).

7. **Vulnerability of water environment under stress in changing climate**

Key issues related to water resources development have increased the vulnerability of water resources in Indonesia that is primarily determined by population pressure on environmental health. Complexity and limitations in assessing freshwater vulnerability were briefly discussed in Gleick [14] and section only identifies some ideas on vulnerability measure related to risks and water stress.

Global climate change has increased uncertainty on the availability of water resources and generating more serious problems of water scarcity in Indonesia, with changing seasonal climate patterns and weather extremes; Measure of vulnerability can be express as follows:

\[
\text{Vulnerability} = f(\text{Hazard}; \text{Susceptibility})
\]  

Hazard types include natural and man-induced hazards.

Susceptibility of social and physical environments would depend on capital resources and basic services, demographical conditions and subjective human choices, institutional relations, networking and natural constraint representing resources conditions/capacities.

Risks of water stress were to be determined by vulnerability and exposure to water-related hazards, and capacity of water resources as natural constraints.

\[
\text{Risk} = (\text{Vulnerability} \times \text{Exposure}) / \text{Natural resources capacity}
\]
Luo et al. [15] presented water stress as measures of sectoral water uses (municipal, industrial, and agricultural) and expressed as a percentage with respect to the total annual water withdrawals as extracted from annual available blue water. Higher water stress values (score from 0 to 5) indicate more competition among users. It is important to note the inherent uncertainty in estimating any future conditions, particularly those associated with climate change, future population and economic trends, and water demand.

| Country  | All sectors | Industrial | Domestic | Agriculture |
|----------|-------------|------------|----------|-------------|
| Singapore| 5.00        | 5.00       | 5.00     | No data     |
| India    | 3.70        | 3.25       | 3.19     | 3.76        |
| China    | 3.19        | 3.08       | 2.95     | 3.33        |
| Indonesia| 2.76        | 2.87       | 2.70     | 2.73        |
| Philippines| 2.63      | 2.47       | 2.43     | 2.92        |
| Japan    | 2.31        | 2.25       | 2.23     | 2.49        |
| Thailand | 1.83        | 1.65       | 1.49     | 1.86        |
| Malaysia | 0.97        | 0.91       | 0.84     | 1.42        |

Source: Luo et al. (2015)[15]

Additionally, care should be taken when examining the change rates of a country’s projected stress levels between one year and another, because the risk-score thresholds are not linear. Table 3 shows Indonesia position among some selected countries in Asia with medium to high values (20 – 40% level) of water stresses for the different sectors of water withdrawals. Indonesia with overall score value 2.76 of water stress ranking already considered at medium to high level. Interpretation of this water stress score could be misleading as it is defined with respect to total water withdrawals that is constrained by water infrastructures. Is it really indicate as real water stress of a river basin will be evaluated further in the next section on evaluation of levels of water security for some major rivers in Indonesia.

8. Levels of water security for some major rivers in Indonesia

Water stress ranking as stated above was defined as total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available blue water and is used as an indicator of water stress of a country [15]. Water withdrawals are those acquired from potential or dependable stream flows and certainly will become real water stress if the withdrawals already utilized and reach the potential capacity. In the case of river basins in Indonesia, total water withdrawals are still limited to existing water infrastructures and is to be considered here as water security of a river basin or a region estimated as overall level of water being withdrawals or utilized from potential water resources as provided from dependable water flow, especially from existing stream flows.

Table 4 below shows these levels of water security for some major rivers in Indonesia as also presenting the un-utilized water of the rivers that flow directly to the sea, comparing situations for those in Java island and from Sumatra as given for Musi river that utilized only two percents of available dependable water at annual average of river discharge of 3,190 m$^3$ s$^{-1}$ that is equivalent to 100.58 billion m$^3$ year$^{-1}$. Apparently, the level of water being utilized for most rivers is low and adopting criteria complementary to levels of water stress in the previous section can be said that water security of most
river basins in Indonesia is still at high water security level or can be stated that Indonesia has a low risk of water stress. However with high seasonal fluctuation, water scarcity is real during dry seasons for rivers in Java Island, that suggest the needs for improvement of water storage infrastructures to regulate this seasonal imbalance. Such water balance information or regional water assessment for most major rivers in Indonesia should be more readily available from regional water resources agency (BBWS – Balai Besar Wilayah Sungai) all over Indonesia or through National Water Assessment report published as country report by International Agency such as Asian Development Bank [17] or from FAOSTATS/AQUASTATS database.

9. Water security of the Citarum basin: a measure of carrying capacity

As illustration of sustainability analysis considered here the Citarum basin, where a simple water balance supply-demand analysis was carried out to determine the carrying capacity of the river basin, by calculating the water availability from existing supply to satisfy the total water demands in 2010 condition and the future in 2030, and sustainability can be evaluated using the mass conservation law, as follows (more detailed discussion is presented at Pawitan et al. [18]. Citarum is the largest river basin in West Java with three large cascaded reservoirs that have total storage capacity about six billion cubic meters and represent the most developed river basin in Indonesia serving a total population of about 30 million people.

Estimated water availability in 2010 and 2030:
- dependable river discharge 182.3 m$^3$ s$^{-1}$ (2010) and 212.5 m$^3$ s$^{-1}$ (2030)
- based on trend/rate of change + 1.51 m$^3$ s$^{-1}$ (1922-1980)

Estimated water demand in 2010 for the different water uses was:
- paddy irrigation 175 m$^3$ s$^{-1}$ (satisfied from Jatiluhur reservoir with effective storage 2,100 billion m$^3$)
- fisheries 10 m$^3$ s$^{-1}$
- electric power 9.5 m$^3$ s$^{-1}$
- DMI 20 m$^3$ s$^{-1}$

Water demand in 2030 is + 10~100 m$^3$ s$^{-1}$ or + 0.5 ~5 m$^3$ s$^{-1}$ year$^{-1}$ based on annual incremental change as follows:
- paddy irrigation - 2000 ha year$^{-1}$ equivalent to: - 2 m$^3$ s$^{-1}$ yr$^{-1}$
- fisheries + (0.5 ~2) m$^3$ s$^{-1}$ yr$^{-1}$
- electric power - no change
- DMI + (2 ~5) m$^3$ s$^{-1}$ yr$^{-1}$

Apparently considering these supply-demand using a simple water balance analysis, even at condition in 2010, the carrying capacity of the lower Citarum basin was overshot already at water demand level of 204.5 m$^3$ s$^{-1}$ that exceeded the average water available at 182.3 m$^3$ s$^{-1}$, and to balance...
the increasing demands was to be achieved only by sacrificing part of the competing water demands that need some kind of trade-off criteria. The likely sacrifice was through restricting more on the agricultural irrigation water demand, either by allocation reduction of irrigation water or to keep up agricultural production through increase crop productivity and improve efficiency in irrigation water use adopting the four-factor concept to produce more for less water, such as the crop-water productivity strategy. In the long term, irrigation water allocation might need to be reduced further to 60% only of available water withdrawal from existing dams to satisfy the increasing higher value water demands for domestic, municipal and industrial (DMI) water users by 2030.

10. National programs related to the water resources development
As implementation of integrated water resources management (IWRM) concept that has been promoted at the global scale through the International Hydrological Program (IHP) Unesco, many national action programs partly play a role as climate change adaptation and mitigation actions have been executed in Indonesia as national movements as multisectoral efforts, and some are as follows:

- GN-KPA – national movement on a partnership for the safeguarding of water resources with river basin organizations as leading agency presently under the Ministry of Public Works and Public Housing;
- GN-RHL – national movement for land and forest rehabilitation promoted by the Ministry of the Environment and Forestry as leading agency;
- National Program on Integrated Agricultural Management Field School, or form for more sectoral programs, such as:
- ESP – Environmental Services Program, a project under the Department of Forestry supported by the US Agency for International Development;
- SCBFWM - Strengthening Community-Based Forest and Watershed Management In Indonesia, a pilot project under Department of Forestry supported by UN Development Program; and
- P4MI – Poor Farmers Income Improvement through Innovation Program, a pilot project under Department of Agriculture that is supported by the Asian Development Bank.
- etc.

11. Concluding remarks
Global climate change that might occured abruptly has been recognized which could have dire socio-economic consequences and has increased uncertainties to the impacts of population pressure through extensive land use and cover changes, environmental degradation and water-related disasters on availability and vulnerability of Indonesia water resources that needs the anticipated adaptation and mitigation actions using evidence-based scientific principle from empirical observations.

Current necessary intensification of agricultural development in Indonesia with new planned constructions of series of dams and irrigation infrastructures would certainly increase pressure on availability and vulnerability of this limited renewable freshwater resource with regional differences. Water stress has occurred mostly in Java Island with serious seasonal water scarcity during dry seasons, though nationally Indonesia is blessed with sufficiently abundant water resources at water availability index averaged at 18,000 m³ capita⁻¹ year⁻¹ (2010).

Water resources development and management in Indonesia under stress in changing climate is considered still in low risk of water scarcity nationally though for Java Island and many developing urban areas already at high water stress level where sustainability could be achieved only through trade-off and balancing the competing water demands, satisfying the law of mass conservation as a sufficiency condition. These high-risk water stress areas would need development of water storage and irrigation infrastructures and adoption of crop-water productivity strategy to improve water use efficiency for food and agricultural production and ensure water and food security of the country.
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