WATER AVAILIBILITY FOR AGRICULTURE SECTOR: CHALLENGES AND RESOLUTION STRATEGY

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Abstract

Water is one of the factors that contribute to the growth of crops. Water supply in certain area determines the development of agricultural site in those areas. Ironically, even tough it's an important source in agricultural sector; there are so many problems of water supply in this sector.

The main problem of water supply in Indonesia is the imbalance between the needs and the supplies of water, looking from the perspective of space and time. Looking from the perspective of space, the water supply in the Island of Java is only 4.5% of total water supply nation wide, but 65% of Indonesian population which is mostly located in that area uses the water.

Beside the imbalance between the needs and supplies of water, the water problems in Indonesia show the fact that there are many damages in watershed. Estimated about 458 watersheds are damage, 282 other watersheds need to be taken care of through a conservations and rehabilitations of the land.

The other irrigation problems are inefficiency of irrigation services. In 2002, the Indonesia irrigation network able to serve 6.77 M ha of rice field. However about 1.67 M ha (about 25%) of it was not function normally.

To deal with the problem below, conceptual and planned anticipations are needed comprehensively and holistically. The Department of Agricultural had prepared many strategies, policies and actions to deal with the problem or water supply in this time and the times to come, including identification and development of technological innovation. Many innovation system and adaptive agribusiness approach that had been developed are PTT development, SRI, IP 400 and others. Agricultural Research Bureau had also prepared many technological innovations and tools from varieties site which is prime and adaptive varieties that can survive in drought or flood, growth fast, etc. From technological site are referring to opening a land, fertilization, management of soil and water that are efficient and environmentally friendly.

I. INTRODUCTION

Water is one of the sources that are essential to every agricultural production system, especially agricultural crops that consume more water. The role of water contribute to over harvesting of rice in 1984 that reach up to 16% of on going total production or rice nationwide, interaction of water-variety-fertilizer contribute about 75% (World Bank, Fagi et al, 1998). Waters not only related to agriculture but also determine potential of extensification of a land, width of planting area (Ha/season), intensity of planting (IP) each year and determine the quality of agricultural products.

High water contribution is not actually balance with the use of water efficiently in production system of agriculture. Wasting of irrigation water at the water source and limited supply of water supply in the end of irrigation cannel are examples of poor water management. As a result, the intensity of planting in a planting area is decreasing in an extreme condition (IP) from 300 decreases to 100, because the use of water for irrigation had to be in turn for each land. Not only damaging the cannel those conditions also decreases the revenue of cannel investation.

Quantity of national water source is very large, but in reality water is still always a problem, for example drought or flood that can disturb the maturity and on going national agricultural production system. Those problems mainly cause by high diversity of water supply with poor management and efficiency. As a country with many island, had wet tropical climate and variety of rain fall result variety of water supply spatially and temporally.

Water supply for agricultural purpose and other sectors can be disturbed because of the limited supply of water spatially and temporally in drought season. In reverse, on rainy season high rainfall and damages of many watershed cause limited volume of water that can be reserved through infiltration and interception, the rests than being transferred into run off. In quantity this phenomenon is marked by high peak discharge and shortening of watershed response times. Fluctuative water distribution will be disadvantage for dry land agriculture that depends on water from rain falls. Conversion of forestry land into agriculture land and also conversion of agricultural land into non-agricultural land are increasing. The increasing of non agricultural land cause the decreasing of capacity for water reservation in watershed, so only few rainfalls that can be infiltrated to the soil, meanwhile the rest of the rain falls forms a run off.

Because of that, anticipation strategy and preparation of adaptive technology are key aspects that had to be "Strategic Plan in The Department of Agriculture" to deal with the threat of water shortening caused by environmental damage and climate change.

II. PROBLEME OF WATER RESOURCES AVAILABILITY IN INDONESIA

The main problem of water supply in Indonesia is the imbalance between the needs and the supplies of water, looking from the perspective of space and time. Looking from the perspective of space, the water supply in the Island of Java is only 4.5% of total water supply nation wide, but 65% of Indonesian population which is mostly located in that area uses the water. From perspective of time unequal water distribution shows by overflow supply of water in rainy season with 5 months duration that reach up to 80% of potential water supply, otherwise in dry season with the durations of more or less 7 months the supply of water is only 20%.

According to the analysis of availability – need balance through out dry season, Island of Java and Bali in 2003 are experiencing deficiency as much as 13.1 billion cubic meter, while in Nusa Tenggara experiencing deficiency as much as 100 million cubic meter (Table 1).

Table 1. Water balance during dry season year 2003 and 2020

Island	Availability ($x10^9$ m^3)	Demand ($x10^9$ m3)			
		2003	Balance	2020	Balance
Sumatera	96.2	11.6	Surplus	13.3	Surplus
Java-Bali	**25.3**	**38.4**	**Deficit**	**44.1**	**Deficit**
Kalimantan	167	2.9	Surplus	3.5	Surplus
Nusa Tenggara	**4.2**	**4.3**	**Deficit**	**4.7**	**Deficit**
Sulawesi	14.4	9	Surplus	9.7	Surplus
Maluku	12.4	0.1	Surplus	0.1	Surplus
Papua	163.6	0.1	Surplus	0.2	Surplus

Source: Sub Directorate of Hydrology, Ministry of Public Work (2003).

Beside the imbalance between the needs and supplies of water, the water problems in Indonesia show the fact that there are many damages in watershed. Estimated about 458 main watersheds are damage, 282 other watershed need to be taken care of through a conservations and rehabilitations of the land.

Other problem is irrigation service that is not being done optimally. In 2002, irrigations networks that are built in Indonesia are supposed to deal with 6.77 million Ha (25%) of rice field, but estimated about 1.67 million Ha of rice field not function optimally.

This is happening because of uncompleted network system of irrigation, inadequate water supply and unprepared and conversion and also unprepared rice field .

In the Island of Java, conversion of land is very worrying. Base on analysis done by Irawan *et al* (2001), in the period of 1981-1999 there had been a conversion of rice field as much as 1.002.055 Ha, Even though there had been an addition as much as 5.18.244 Ha of rice field but there is also decreasing in rice field as much as 483.831 ha. While an analysis done by Sutomo (2004), In the period of 1999-2002 there had been a conversion of rice field as much as 167.150 Ha, that cause shortening of rice field in the Island of Java as much as 107.482 Ha.

Table 2. The balance of wetland rice field 1981-1999 and 1999-2002

Region	**Conversion**	**Increment**	**Balance**
	Ha		
Year 1981-1999[1]			
Java	1.002.055	518.224	-483.831
Out of Java	625.459	2.702.939	+2.077.480
Indonesia	1.627.514	3.221.163	+1.593.649
Year 1999-2002[2]			
Java	167.150	18.024	-107,482
Out of Java	396.009	121.278	-274,732
Indonesia	563.159 (±190.000 ha/yr)	139.302	-423,857

Sumber : 1. Irawan *et al*. (2001)
2. Sutomo (2004)

III. PRESENT AND FUTURE WATER REQUIREMENT FOR AGRICULTURAL SECTOR

Water consumption in agricultural sector is determined by volume of water consumed by paddy crops, as main commodity in agriculture paddy consume a lot of water for growing. Consumption of water for paddy crops for growing is about 450-700mm (Doorenbos dan Kassam, 1979). Consumption of water had to be fulfilled in every phase of the crops growth so quantity of rain falls in a region had meaning for rainfalls volume and distribution of rain all year long.

Base on analysis by Sub Directorate of Hydrology, Public work Department, consumption of water in agricultural sector in 2002 reach up to 80% of total water consumption in Indonesia. Base on demand analysis and water availability island base, the biggest ratio between demand and availability of water for Island of Java reach up to 25%. Consumption of water for agriculture sector in Java these days reach up to 1.283 m^3/s (Table 3) or equal to 14.188 MCM (*million cubic meter*) for each planting season.

Table 3. Water availability and actual requirement for irrigation and other purposes, year 2002

Province/Island	Average water availability (m^3/dt)	Water Requirement in 2002		
		Irrigation	Other purposes (DMI)	Total
DKI Jakarta	317	76	59	135
Banten	252	29	3	32
West Java	2.171	372	53	425
Central Java	1.665	337	26	363
D.I. Yogyakarta	175	50	6	56
East Java	1.355	419	48	467
JAVA	**5.936**	**1.283**	**194**	**1.478**
INDONESIA	**101.664**	**2.554**	**659**	**3.213**

Source: Sub Directorate of Hydrology, Ministry of Public Work (2003).

Base on a research by Public Work Agency, needs for irrigation on rice field in Indonesia is about one liter per second per hectare counted with an assumption that on going water loss because of percolation is about 1-2 mm per day (Notohadiprawiro, 1992). This assumption only validated on a land that had already form a solid impervious soil layer. This means that the land had already been used as a rice field for many years.

Base on exact irrigation score 1 l/s/ha, means to water an hectare of rice field in one planting season 11.059 m^3/ha or equal to 1.106 mm of water is needed for irrigation. One period of planting season is assumed to be 128 days calculated by adding length of time for preparation the land which is two days before planting the seeds, duration of seeding for 20 days, for maturation of paddy crops is needed about 120 days counted from the day the young crops being transferred to the rice field until harvesting time. Irrigation water stopped 14 days before harvesting, so irrigation of rice field needs 2+20+(120-14) = 128 days.

For new rice field, exact irrigation score of 1 l/s/ha is too low. Many soil in Indonesia had on going percolation higher than 2 mm a day. The example of the soil are light soil which came from volcanic ash like the one located in DIY, Andosol soil in mountain area that had ashy texture and had a very high organic matter and peat soil.

Base on Murukami measure (Notohadiprawiro, 1992), for turning a land into a muddy field, flattening the surface of soil and keeping the soil watery for 2 days before planting seed, require 170 mm of water. Evapotranspiration during seeding for 20 days takes about 66 mm of water during rainy seasons (RS) or 130 mm of water in drought season (DS). Percolation starts from seeding to harvesting with an on going of 7 mm a day for 140 days takes about 980 mm of water. Evapotranspiration for 120 days during maturation of the paddy crops is 528 mm in RS or 660 mm in DS. These score are equal to exact irrigation score 1.6 l/s/ha in RS or 1.8 l/s/ha in DS. As a guidance score, the rate for exact irrigation score for new rice field is 1.7 l/s/ha or equal to 1842 mm.

Base on Agricultural Research Bureau analysis, Java island had the potential to open a new rice field as big as 14.393 ha of rice field. Those Potential are spread as much as 7.447 ha in West Java, 4.156 ha in East Java, 1.488 ha in Banten and 1.302 ha in Central Java. Potential or newly opened rice field in Java Island is only 0.14 % of total potential newly opened rice field in Indonesia.

Table 4. Potency of new wetland rice field in Java.

Island/Province	Potency wetland rice field (Ha)		
	Swampy land	Non Swampy land	Total
DKI Jakarta	0	0	0
Banten	0	1.488	1.488
West Java	0	7.447	7.447
Central Java	0	1.302	1.302
DI Yogyakarta	0	0	0
East Java	0	4.156	4.156
Java	**0**	**14.393**	**14.393**
Indonesia	**2.978.380**	**5.297.593**	**8.275.773**

Source: Indonesian Agency for Agricultural Research and Development (2007)

Base on an assumption, for newly opened rice field it is required an exact irrigation score as much as 1.7 l/s/ha, so to support the development of newly opened rice field in Java Island additional irrigation supply is needed as much as 24.5 m^3/s or equal to volume of water consumption about 270.5 MCM for one period of planting season.

III. THE TREND OF WATER UTILIZATION FOR NON AGRICULTURAL PURPOSES IN JAVA AND ITS IMPACT ON AGRICULTURAL SECTOR

According to BCEOM in Sosiawan, H (2004), Projection of water consumption in agricultural sector, domestic, municipal and industrial sector that are calculated base on population growth until the year of 2005 in Pantura Java area as a central base of food in Indonesian had the tendency as follow: consumption of water for agricultural purposes drop as much as 25%, while consumption of water of non agricultural purposes rises 30-40% from the condition in 2002. Dealing with the need of water for irrigation and because of agricultural sector had the irrigation water for free, to maintain the balance of water supply in a reservoir, the burden of water deficiency is given to agricultural sector by reducing the share or water for irrigation.

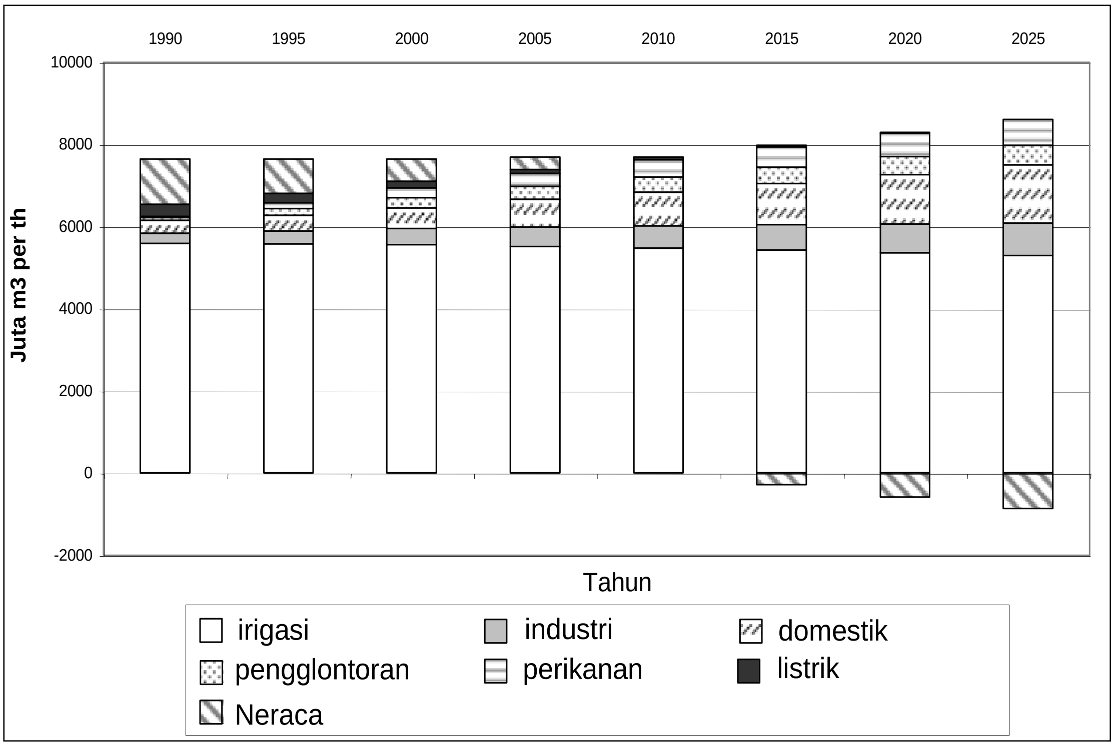

Figure 1. Projection of water requirement for various sectors in Northern Part of Java

Consumption of water for non agricultural purposes (DMI) base on the assumption of population growth is about 1.6% a year, industrial sector rises as much as 20% a year after the economic crisis. The rise of population and industrial sector result the rise of water consumption for DMI in 2005, 3.5 times more than in year 1990. Meanwhile the result of environmental damage and pollution, availability of utilized water are decreasing. Because of the agricultural sector had the irrigation for free, it is possible that water deficiency will be burdened to the agricultural sector.

The rise of water consumption for non agricultural sector (domestic, municipal and industry) for the last 10 years is very significant, resulting the decreasing or ability for supplying irrigation water in those area. The problems worsen because of the diversity of water supply every time and every region in drought season, so it can cause disability to the reservoir in supplying water for agricultural, municipal and domestic purposes.

Fluctuation of water supply will be less advantage to the water service company such as Perum Jasa Tirta as Government Company (BUMN), because quantity of water are relatively constant even when it is used it's relatively decreasing because of the environmental damage and pollution, meanwhile real demand of water for domestic and industry in theory tend to rise. Base on the assumption of on going population, urbanization and development of industrial sector, it is estimated that in 2015 total demand of water will be higher than the sum of water that are reserved in Jatiluhur reservoir.

Looking upon water demand for agricultural sector and non agricultural sector and also the capacity of Jatiluhur reservoir for the last 10 years and the projection of water demand in the future as a result of competing in water consumption between domestic and industrial sector, so it can be predicted that in 2025 share of water for irrigation which is free of charge will decreased about 25% from 2002. The things will worsen because of efficiency of irrigation water distributions that are very low. That can cause loss of irrigation water from reservoir to the rice fields more than 35%. Logical consequences from the decreasing of water demand share versus agronomic conditions of paddy farming is inability to fulfill the need of water in many phases of growth, so the production will surely decreased around 30%.

Simulation of crops water balance (Karawang Regency Case study, 90.300 ha of irrigation area) shows that in normal years, region that went through deficiency of water for planting is type III irrigation (24.600 ha) and type IV irrigation (14.300ha). In planting season period I, deficiency of planting water are more than 50% that happen in seeding and maturity phase, but it will not influence the decreasing of the result significantly. Meanwhile in planting season period II deficiency of water will happen in dumping phase in irrigation region type II and IV, each will be 25 % and 22% resulting reduction of product as much as 62% and 56%. Irrigation type I (23.700ha) and irrigation type II (27.700 ha) that are given water one month earlier had the chance to fulfill the water consumption better. Deficiency of water for crops only happen in vegetative phase 17% and 20% each that happen in planting season period I. Those conditions cause the reduction or the results 17% and 20% each. In El Nino year deficiency of water for planting was found in all regional irrigation type and significantly influence the quantity of the product. Water deficiency that happen in dumping phase sits around 22-26% causing the reduction of product quantity as much as 56-64% and generally it happen in planting season period II (Sosiawan, 2004). Recapitulation of water planting balance result and the correlation with water deficiency and potential of reduction in quantity of crops product that are projected in 2025 will be displayed in Table 5 .

Table 5. Simulation result of water balance related with water deficiency and prediction of water losses in 2025

Group of Irrigation	*Normal Year*								*El Nino*							
	Water Crop Deficit (%)				Decreasing yield Potentiality (%)				Water Crop Deficit (%)				Decreasing yield Potentiality (%)			
	Dv	Fl	Fg	Ma	Dv	Fl	Fg	Ma	Dv	Fl	Fg	Ma	Dv	Fl	Fg	Ma
Telagasari (Gol 1)																
- rainy season	17	0	0	27	17	0	0	3	38	22	3	0	38	56	1	0
- dry season	0	0	3	0	0	0	1	0	17	0	4	38	17	0	1	6
Rengasdengklok (Gol 2)																
- rainy season	20	0	0	0	20	0	0	0	45	6	0	0	45	15	0	0
- dry season	0	0	14	27	0	0	4	3	20	26	14	34	20	65	4	3
Batujaya (Gol 3)																
- rainy season	14	0	50	57	14	0	13	7	18	0	12	63	18	0	4	6
- dry season	7	25	23	34	7	62	7	4	26	26	55	52	26	64	17	8
Cibuaya (Gol 4)																
- rainy season	14	6	23	52	14	14	7	8	22	0	0	63	22	0	0	6
- dry season	7	22	26	36	7	56	8	4	30	25	2	84	30	63	1	8

Dv : vegetative stage, Fl : flowering stage, Fg : Grain formation, Ma : Ripening

Illustrations above shows that by assuming the potential of paddy production of maximum 6 ton/ha, for the normal years potential of paddy product loss as much as + 144.000 ton/year that came from type III and IV irrigations. Meanwhile in El Nino year potential of paddy loss will reach up to + 324.000 ton/year, base on the result of simulation in the same period throughout the region will experience the water deficiency that will influence the reduction of product quantity. If the conditions are projected for all paddy production center in the north of West Java that had the land source characteristics, climate and water irrigation system that are relatively the same, with total of space as much as + 242.000 ha, so potential loss in normal years will reach up to + 435.600 ton/year. The conditions will worsen in an abnormal climate such as El Nino that occurred every five years and result the reduction of product quantity up to + 871.200 ton/ years.

If Pantura region of Java still being defended as national food storage, those condition will need anticipation by participation of many Government policy in agricultural sector especially about management of water source in food production center base region in Pantura Java by prioritizing irrigation water availability that can guarantee to fulfill the need of planting water.

IV. ADAPTATION TECHNOLOGY COOPING WITH WATER SHORTAGE DUE TO THE IMPACT OF CLIMATE CHANGE

The dynamic characteristics of climate, variability and climate change are meant to be and will happen. But because of global warming and many human activity will fasten the dynamic climate change naturally. Climate change had many results in many aspects of life and human activity. Even though agricultural sector contribute as the cause of climate change, agricultural sector is after all just a victim and very vulnerable within the climate change, especially National Food Security. As an impact of climate change in national food security start from negative influence to resources such as land and water, irrigation as an agricultural infrastructure until production system through the productivity, width of plantation and harvesting.

Department of Agriculture through Agricultural Research Bureau had developed many adaptive technology to face threat of water deficiency as the result of climate change.

4.2.1. Adjustment of cropping pattern and cropping calendar

Adjustment of time and plant pattern are strategic ways in approaching for adaptation to reduce or to be alert for the impact of climate change cause by sifting of season and change of rainfall pattern due to global climate change. Department of agriculture had published a map of Java Island planting calendar at the scale of 1: 1.000.000 and 1: 250.000 to show potential pattern and timing for plant food especially paddy, base on the potential and dynamic of climate and water resources (Las, *et al*, 2007). Map of planting calendar is made according to the condition of the existing farmer planting pattern and three scenario of climate which is wet year (WY), normal year(NY), dry year (DY). Illustration 2 shows example of a map planting calendar for paddy crops in dry years. Map of planting calendar comes with climate prediction to predict the next climate phenomenon, so plan for planting can be adjusted with the condition of climate and water resources.

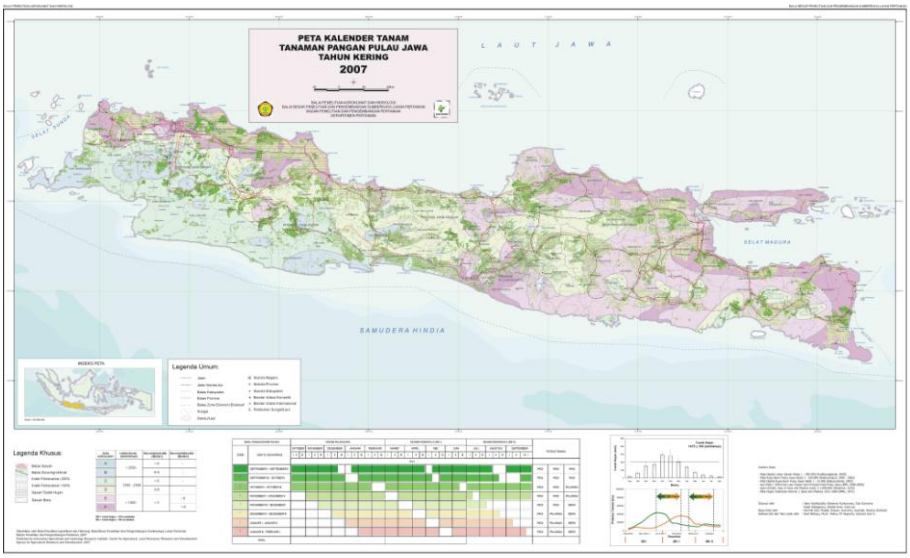

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Figure 1. Cropping calendar map of Java Island, scale 1:1000.000 dry year (Sources: Las, *et al.* 2007)

4.2.2. Adaptive High Yielding Variety

Crops variety for un-irrigated land (dry land)

To anticipate the dry climate, there had been released many variety that had the specialty to survive pest and disease and also very tolerated to be planted in dry climate area. The commodity below that are included are paddy variety (Dodokan dan Silugonggo), Alternative paddy variety (S 3382 and BP 23), soy bean variety (GH SHR/WIL-60 and GH 9837/W-D-5-211), peanut variety (Singa dan Jerapah), green bean variety (Kutilang), alternative green bean variety (GH 157D-KP-1), corn variety (Bima 3 Bantimurung, Lamuru, Sukmaraga, Anoma).

High Yielding Variety of Crops Adaptive to Flood

Swampy land had a high potential and prospect in developing future agriculture, especially to support national food security. Those lands are always saturated by water or waterlogged in a certain time of the year. To optimalized the land it had been found many alternative breed of paddy that can tolerate water saturated land, the varieties are: GH TR 1, IR69502-6-SRN-3-UBN-1-B-1-3, IR70181-5-PMI-1-2-B-1, IR70213-9-CPA-12-UBN-2-1-3-1 and IR70215-2-CPA-2-1-B-1-2.

4.2.3. Water and Climate Management Technology

In additon to water resources, Department of agriculture had started with a program for technology development to rise the potential of water resource. Management of water resource and climate had an important role and it is one of the success full keys to increase food production in dry land and rice field land. Many technologies in water and climate management are: water harvesting technology, irrigation technology, climate prediction technology, and determination of planting time and planting pattern technology.

Water harvesting technology

Harvesting technology is one of the alternative technologies of water management base on the principal of reserving excess water in rainy season and using it in drought season for irrigation purposes. Many rain harvesting technology that had been applied by many are on farm reservoir (*embung*) and channel reservoir that does not take up agricultural land.

Irrigation Technology

Many irrigation technologies had been developed to face water deficiency of plantation such as: a) chain wells, b) capillarity irrigation, c) drip irrigation, d) semi-wet irrigation in wet land, d) rotational irrigation, e) alternate wet/dry irrigation

a) Chain wells is one of alternative technology of irrigation which is very suitable when it is applied for sandy soil. This land had the ability to loose trapped water so it can't reserve the water for a very long time. The principal of chain wells is to store water in a chain of storage tanks in the form of cylinder in which each storage tank is connected by capillary pipe.

b) Capillary irrigation is suitable to be developed in the slopping land areas with limited water resources. The principle of capillary irrigation is : utilize water from spring or river and distributed it to storage tanks by gravitation using PVC pipe. The water from storage is distributed to the crops using capillarity plastic hose.

c) Drip irrigation is an alternative irrigation technology that uses the limited availability of water efficiently and to increase the point of water usage. This technology is very suitable in dry land with dry climate in the flat land area. The principle of drip irrigation is distributing water from the storage tank which is placed in a higher position using irrigation hose. Crop water requirement is supplied from storage tank through special design of irrigation hose so that water can be applied to the root zone of the crops at the constant discharge in every outlet using dripping system. This technique is very highly efficient in the term of water use but only suitable for high value commodities.

d) Semi-wet Irrigation is a method of supplying water at certain level without flooding the crops. Water use efficiency using this method is 2-3 times higher than continues flooding irrigation.

e) Rotational irrigation is a method for irrigating crops in a certain area within certain time period. Irrigated area store water and use it up to the next rotation period. Rotational irrigation for rice does not decrease the yield even increase the yield.

f) Alternate wet/dry irrigation is a technique to irrigate water at certain level volume, and the next irrigation is supplied after water level decrease. This technique gives higher rice yield than continuous flow irrigation and rational irrigation

4.2.4. Planting calendar and Crops water requirement

Determination of planting calendar base on water availability aim to reduce the risk of failure in harvesting and eficiency of water usage for irrigation. Balitklimat had developed WARM Software to determine planting time, time of irrigation and irrigation dosage. Base on variety of comodity that are specialized in a certain area, analysis had been implemented to find out the potensial of timing duration for normal year, El-Nino and La-Nina. Indicator for determining planting time is potential of product loss (PPL). Crops that had potensial production loss less than 20% is a plant that can be potentially planted in a certain period.

VI. CLOSSING REMARKS

Threat or water deficiency these days believed to be not just an issue, but it had become reality and needed real action together globally, regionally and nationally. Department of Agriculture treats the threat of water deficiency with the development of agricultural adaptive technology. Adaptation is an action of adjust natural and social system to face the negative impacts of climate change.

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