Climate Change Risk and Adaptation Assessment

Greater Malang

Sectoral Report
Agriculture

June 2012

Ministry of Environment

Climate Change Risk and Adaptation Assessment for the Agriculture Sector – Greater Malang

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Climate Risk and Adaptation Assessment
For the Agriculture Sector – Greater Malang

Draft Final Report

by:

Ruminta
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June 2012

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Chapter I Introduction

1.1 Background

There is strong evidence that global warming over the last century causes the annual increase of average global temperature, changes in rainfall patterns, the increase of sea levels, and the rise of frequency and intensity of extreme weather. The study of the Intergovernmental Panel on Climate Change-IPCC (2007) showed that climate change has occurred with some evidence; the increase of the average global temperature (an increase of 0.76° C from 1899 to 2005); the increase of the global average sea level (an increase of 1.8 mm per year from 1961 to 2003); the increase of the uncertainty and intensity of rainfall; flood, drought and erosion become more frequent; Also, the extreme weather phenomena, such as El Nino, La Nina, cyclone, tornado, and hailstone, become more frequent. Furthermore, global climate change affects various aspects in human living systems, that are (1) water management and resources, (2) agriculture and food availability, (3) terrestrial and freshwater ecosystems, (4) coastal and ocean; (5) human health; (6) residencies, energy, industry, and financial services.

Although many uncertainties about the location and magnitude of climate change, there is no doubt that climate change is causing a major threat to agricultural system. Developing countries are susceptible to this threat because their economies are closely related to agriculture and their livelihoods depend directly on agriculture and natural ecosystems. Therefore, climate change has the potential to act as a "risk multiplier" in the poorest parts of the world, where agriculture and natural resource-based systems fail to accommodate the climate change. Thus, agricultural systems in developing countries must adapt to climate change in order to millions of farmers could face the real and direct threat to food availability and livelihoods. Even without climate change, many agricultural systems in developing countries are approaching a crisis point.

Climate change threats crop production system and therefore also threats the livelihood and food availability for billions of people who depend on agriculture. Evidence suggests that poor population suffer more than rich population, such as industrialized countries (IPCC 2007), because of the effects of climate change. Not only the relatively poor countries will experience more severe impacts, but the impact also threats those who are lacking resources to prepare and overcome environmental risks. Agriculture is the most vulnerable sector to climate change because of its dependencies on climate and weather and the people who are involved in the agricultural sector tend to be poorer than their counterparts in the city.

Climate change to some extent can be indicated in Indonesia. These indications are supported by the results of studies on climate change in the Indonesian region in recent years (BMKG 2007). This climate change is indicated by the flood, drought and the shift of rainy season. In recent years, the shift of rainy season causes the shift of planting and harvesting time of food commodities (rice, pulses and vegetables). In addition, flood and drought cause planting and crop failures, and even *puso* (*i.e.* crop does not produce grain)

In Indonesia, change of rainfall patterns is probably the biggest threat, because so many farmers depend directly on rainfall for their agricultural activities and livelihoods. Every changes of rainfall pose a great risk. Rainfed agriculture is very susceptible to climate change, if the farming activities remain unchanged. Meanwhile, the quality of fresh water will increasingly affect farming systems in coastal areas due to sea water intrusion and unsustainable irrigation activities. High salinity due to increasing sea level becomes a threat to food crop production in coastal areas because many varieties are not resistant to high salinity. Furthermore, high temperature will affect the agricultural system. Plants are very sensitive to high temperatures during critical stages, such as flowering and seed development. Combined with drought, high temperatures can cause disaster for agricultural lands. Changes in temperature and humidity can also lead to the development and sprawl of pests and plant diseases. Floods and droughts also affect agricultural productions. Floods and prolonged droughts, caused by poor water management and low capacity, make significant decrease in productions.

Based on the monitoring results, conducted by the Ministry of Agriculture in the last 10 years (2000-2009), droughts and floods tend to rise. The average rate of agricultural land area affected by drought is 303,641 hectares with 58,489 hectares of *puso* lands or equivalent to 767,589 tons of dry un-husked paddy (DUP). Meanwhile, 271,381 hectares lands are affected by floods with 79,846 hectares *puso* (equivalent to 774,106 tons of paddy). Then, between 2000 and 2009, there are 332 large flood events per year in Indonesia, which led to an average of 271,381 hectares of rice fields and other agricultural land were flooded (Figure 1.1).

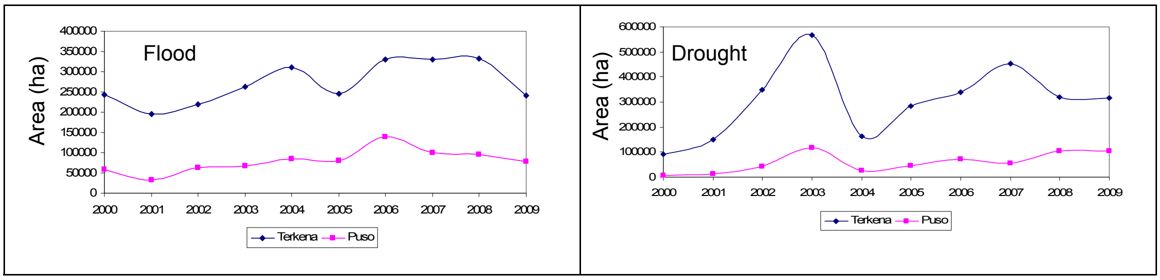

Figure 1.1 Puso land area due to floods and droughts in 2000 - 2009

Climate change in a region is also indicated by the existence of seasonal climate variability. Seasonal climate variability in Indonesia is marked by the occurrence of droughts, unpredictable rains and relatively short period of rainfall. This variability results in harvests and crops failure of food crops such as rice, pulses and vegetables. In other words, seasonal climate variability is one of the main causes of decline in agricultural productions, especially the productions of food crops, plantations, forestry and even livestock.

Extreme climate event (El Nino) illustrates that food production in agricultural sector are highly susceptible to climate changes and anomalies. If there is a decrease in productivity due to crop failure and *puso* then the probability of food insecurity would be high. In the agricultural sector, climate change and extreme climate cause the vulnerability of food productions.

The relation between the El Nino phenomena and the production of three major food crops in Indonesia is shown in Figure 1.2 The El Nino phenomena in the last 20 years occurred in 1994, 1997, 2001, 2003, 2004, and 2006. In those years, El Nino has strong impact on the production of paddy and maize crops in Indonesia. It is clearly visible in Figure 1.2 that the production of paddy and maize crops has decreased significantly in those years.

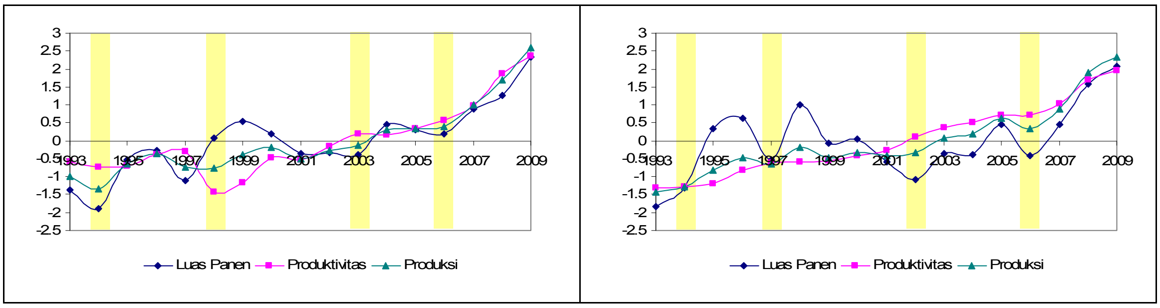

Figure 1.2 The area of harvesting and food crop productions in Indonesia (1993-2009). Yellow lines show the years when the El Nino occurs.

The extent of climate change to affect agricultural systems depends on various factors, including the crop types, operation scales, farming orientations toward commercial or subsistence purposes, the quality of the natural resource bases, and the influence of human and farm manager (for example, education, risk tolerance, age, etc.). Vulnerability is also mediated by institutional factors, including the rules and policies of land ownership, markets availability, capital, insurance, financial support, and technological development and distribution. Diversity of climate patterns, farming systems, social conditions, economy, politic and environment make vulnerability unevenly distributed across regions and social groups in Indonesia. These diversities become a challenge in developing a methodology for vulnerability assessment that accurately captures the spatial dimension of vulnerability in Indonesia. Therefore it is necessary to identify the areas in agriculture, production system, and population which are the most vulnerable to climate change.

Adaptation in the regional level (e.g. Greater Malang) is focused on the efforts to ascertain the objectives of regional development, through the study of vulnerability to support increase of food availability. Food availability in some regions is very susceptible to the threat of climate change. Therefore, the research of vulnerability needs to be conducted regionally to find the vulnerability level of the area and determine the policies and adaptation strategies based on local needs and conditions.

1.2 Greater Malang as a Location Study

Greater Malang is choosed as a site to study the vulnerability of climate change to the agricultural sector because Greater Malang has a large area (3,286 km^2), almost 6.86% of total land area of East Java Propince (47,922 km²). In addition, Greater Malang has three types of agricultural system that are low land (wetland paddy), medium land (dryland paddy), and high land farming. Also, Greater Malang (especially Poncokusumo and Bumiaji Sub-Districts) is the center of apple production in Indonesia. These conditions have the potential to be affected by the impact of climate change.

Another reason, the number of residents in Greater Malang is very large, that is 3,392,634 people living in 41 sub-district. The sub-districts in Greater Malang are Donomulyo, Kalipare, Pagak, Bantur, Gedangan, Sumbermanjing, Dampit, Tirtiyudo, Ampelgading, Poncokusumo, Wajak, Turen, Bululawang, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Kromengan, Ngajum, Wonsari, Wagir, Pakisaji, Tajinan, Tumpang, Pakis, Jabung, Lawang, Singosari, Karangploso, Dau, Pujon, Ngantang and Kasembon (District Malang); Kedungkandang, Sukun, Klojen, Blimbing, and Lowokwaru (City Malang); and Batu, Junrejo, and Bumiaji (City Batu). About 36.5 % of Greater Malang labours are farmers. The large number of people in Greater Malang who have activities in agricultural sector means that they are very susceptible to the effect of climate change.

Greater Malang has various potencies. Some of these potencies include food crops (rice, corn, cassava, etc.), plantations (sugar cane, etc.), fisheries, and livestock, Therefore, Greater Malang is designated as the East Java Province Food Barn. The success of Greater Malang as the East Java Province Food Barn will be in the future influenced by the climate change.

Greater Malang is one of the districts that support East Java Propince food supply, especially rice. Greater Malang can produce 441,567 tons of dry un-husked paddies (DUP) equal to 280,395 tons of rice each year. All of rice production in Greater Malang (280,395 tons of rice is donated to fulfil the Greater Malang food requirement and no contribution to the national rice supply, even a shortage of 143,684 tons for consumption of resident in Greater Malang each year (Malang

Agricultural Office, 2008). To maintain these contributions, the government of Greater Malang implements the National Rice Production Increase (P2BN) program by involving farmers, and then supported by the provision of agricultural productions, especially fertilizer, seed, equipment and agricultural machines, providing reinforcement and capital extension.

Intensive rice farming in Greater Malang is implemented on various types of agricultural land, *i.e.* dryland and wetland. Dry land (upland, dry land or non irrigated land) is agricultural land without flooding water permanently or seasonally, neither by water from rainfall or irrigation. Definition of dry land in Greater Malang is the same as non irrigated land, i.e. land without irrigation facilities (see BPS (2011); Chang (1976); and DeDatta (1981)).

Agricultural land in Greater Malang consists of dry land and wet land. Wetland consists of technical irrigated farm, i.e. farm that always get water throughout the year and rainfed is farm which irrigation depends entirely on rainfall. Currently, annual land area of 148.272 ha, which consist of 32.943 ha or 22.2% of irrigated land, 16.502 ha or 11.1% is the rainfed land, and the remaining 98.827 ha or 66.7% is dry land.

Farm crop in Greater Malang is highly depend on the state of natural resources, especially agro-climatic conditions such as rainfall and the availability of irrigation water. In the event of drought due to dry seasons, the food crops grown in rainfed lowland areas will experience different water stress. The range of average rice productivity in rainfed lowland is between 3.8 and 5.2 tons, rice productivity in irrigated rice fields is between 5.6 and 8.8 tons, while corn productivity is between 5.0 and 8.8 tons per ha (CBS, 2010). Related to rainfall that affect rice production in both irrigated rice and rainfed areas, so the arrangements of planting schedule become important for the rain water is effectively utilized by rice plants.

Food crop productions in Greater Malang, including well irrigated and non-irrigated farms, and dry land, are very determined by rainfall patterns. Achievement of this production is not only caused by low rainfall at planting or during crop growth (*e.g.* during primordial time), but also determined by the rainfall during the flowering phase. Related to the rainfall fluctuations in Greater Malang, the implications of the decline in productivity and crop failure, which led to the decline in crop production, are the hazards of climate change.

1.3 General Objectives

The main objective of this study is to further develop and repeat the VA methodology which is approved nationally and to develop adaptation strategies at semi regional, ascertain its implementation with adequate budgets and funding, including financing development and innovative policy instruments, and formulate adaptation strategy that is appropriate with adaptation options and supported by local authorities. The study on vulnerability of agriculture in Greater Malang on climate change is based on "multi-level micro sectoral approachment" (MsLMSA).

Other objectives of this study are to provide framework to approach the challenge of climate change by forming knowledge basis in climate effect and basic concept about how to build adaptive capacity and long live immunity; to provide critical synthesis from the proof and future scenario of climate change by analyzing and testing the vulnerability of farming sector in Greater Malang on climate variability and climate change; and to identify farming regions which are vulnerable to climate change impacts.

In addition, the research offers an assessment of policy options and investment for practitioners and policy makers, outlining strategies to overcome the threat of climate change and provide knowledge of the available opportunities for poor farmers to face climate change and arrange conceptual framework to build climate change immunity in the agricultural sector in Greater Malang.

There are several activities that need to be done to achieve this goal, that is:

1) Raising awareness about the impact of climate change and its management for local and regional government and stakeholders,

2) Further developing, repeating, and applying the VA methodology, which has been applied to the Lombok island (NTB), to the Greater Malang so the vulnerability of climate change could be assessed for designing good

adaptation strategies and integrate the results into the development plan of local/regional government,

3) Involving climate change adaptation into the development planning of local/regional government,
4) Building adaptive capacity of stakeholders related to the issues of vulnerability and climate change adaptation at the local level,
5) Make aspects of climate change adaptation become effective and disaster preparedness,
6) Support and provide input to policy makers and national development planning, particularly to support strategy and adaptation planning at local level,
7) Develop the capacity of local governments in fiscal and financial sector and improve their ability to access the source of national and international funds.

1.4 Scopes of Assessment

Studying the vulnerability of agricultural sector to climate change in Greater Malang, by examining the hazard possibility and the risk posed by climate change. Developing steps of adaptation strategies to act locally by looking the idea of integrated management, that is implementation of adaptation strategies in coordination, collaboration, participation, equitability, and representatition, by preserving natural resources (agricultural land) with sustainable carrying capacity.

1) Designing conceptual framework and methodological steps for assessing the possible risk of climate change on agricultural sector,
2) Identifying baseline data that is needed to partially determine the level of vulnerability (each sub-district),
3) Data collection and analysis, then interpret the results for the case in Greater Malang,
4) Conduct vulnerability analysis in agricultural sector and the possibility of dangerous climate change in Greater Malang,

5) Predicting, interpreting the results of analysis, and mapping based on the partially vulnerability justification to the region (each sub-district) based on the vulnerability level,
6) Conducting risk assessment of climate change on the opportunities of crop failures, their impact on the performance of the balance of food / food security (supply, distribution, consumption),
7) To formulate the adaptation strategies in agricultural sector (adjusting the cropping pattern, cropping schedule) to respond climate change in Greater Malang,
8) Provide input to local government in preparation of development plan which focuses on climate change on agriculture.

1.5 Research Outcomes

Outcome of this study is the realization of the results in the form of the final report about the vulnerabilities and risks of the agricultural sector in Greater Malang to climate change, and drafting of the steps of participatory adaptation strategies in the form of guidelines based on the top down and bottom up approaches.

Other outcomes of the vulnerability study in Greater Malang are as follows:

1) Risk Analysis and Adaptation Options for Agricultural Sector in Greater Malang based on *micro* level-multi sectoral approach (MsLMSA),
2) Providing and giving relevant information on Vulnerability and Adaptation of Climate Change in Agriculture Sector into Adaptation and Vulnerability of Climate Change Database which will be used by local governments and stakeholders in Greater Malang,
3) Providing input of Risk Analysis and Adaptation Options in Agricultural Sector to the Final Document which provides a systematic guide to integrating adaptation and financing options that fit with the VA basis into the annual sectoral plans (in RPJM now) and the next RPJM (2015-2019) in Greater Malang,

4) Improving the National VA Guidelines for Agricultural Sector based on experience drawn from the implementation of VA in Greater Malang,
5) Contribute to VA Final Report: Risk Analysis & Adaptation Options for Agricultural Sector as a basis for the final report of the VA study in which the recommendations are approved by the regional government of Greater Malang .

Chapter II General Description of Agriculture Sector and Climate Change Issues in Greater Malang

2.1 Overview of Greater Malang

Greater Malang is an area located in the center south region of East Java Province. Greater Malang consists of three regions, namely Malang District, Malang City, and Batu City. The coordinates position of Greater Malang is located between 112°17', 10.90" East Longitude and 122°57', 00.00" East Longitude and between 7°44', 55.11" South latitude and 8°26', 35.45" South latitude. Geographical position of Greater Malang is shown in Figure 2.1.

The area of Greater Malang is about 3,286.5 km^2 (source: Central Management of Brantas River Basin), Greater Malang is the second largest area after Banyuwangi in East Java Province. Topography of Greater Malang is a plateau area which is surrounded by several mountains and lowlands with altitudes of 250-500 meters above sea level (asl). Plateau area is an area of limestone hills (Kendeng Mountains) in the south at an altitude of 0-650 meters above sea level, the slopes of the Tengger-Semeru area in the eastern part stretches from north to south at an altitude of 500-3600 meters above sea level and slopes at the Kawi-Arjuno west at an altitude of 500-3300 meters above sea level. The topography map of Greater Malang shown in Figure 2.1

There are nine mountains and one mountain located in the North, East, South and West region of Greater Malang. Several mountains are Semeru Mount (3676 meters) the highest mountain in the island of Java, Bromo Mount (2329 m), Kawi Mount (2651 meters), Kelud Mount (1731 meters), Welirang Mount (2156 meters) and Arjuno Mount (3339 meters).

The main water sources in Greater Malang are in the form of rivers and springs. There are 10 major rivers in the Greater Malang, namely Brantas, Metro, Jilu, Cokro, Rejoso, Amprong, Welang, Lesti, Ngotok Ring Kanal, and Lahor, among them, the

Brantas River is the largest and longest river in East Java. The Brantas River upstream is located at Batu City area. Critical watershed located in Greater Malang is Braantas river's watershed. Watershed's lack of ability to store water in dry season causes the magnitude and frequency of flooding and sedimentation and silting in the reservoir and rivers are increased. To overcome agricultural water shortage, irrigation has been built to cover 9 irrigation areas (Local Technical Organizer) with total area of **36,824** ha.

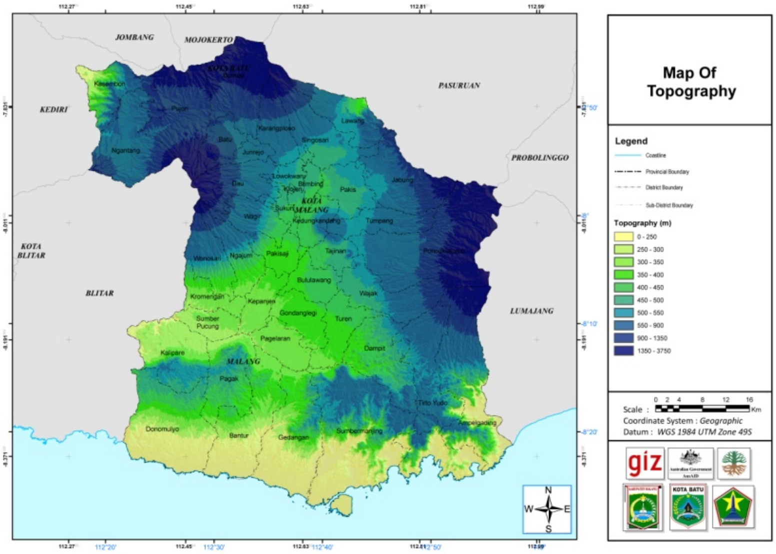

Figure 2.1 Topography map

Greater Malang, which is part of the East Java Province, consists of one district and 2 cities, namely Malang District, Malang City, and Batu City (Figure 2.2). The number of Greater Malang is 41 sub-district (Table 2.1). The number of village in Greater Malang is 394 villages, while the number of ward in Greater Malang is 77 wards (Table 2.1).

The population of Greater Malang in 2010 is 3,429,409 people with population growth rate of 1.4% per year. The population density of Greater Malang is 1,043 people / km^2 (details of population in each district can be seen in Table 2.2 and Figure 2.3). Population growth is relatively high if viewed from the government's load. This implies the need for provision of food that must be continuously improved. On the other hand, this condition reflects the potential of human resources (HR) which its role can be optimized in local development activities in all aspects. The distribution of population can be reference for mapping economic programs and activities that can absorb the local workforce in the agriculture, plantation, and other sectors. It can be seen that in accordance with geographical conditions and natural resource potential, about 17.2 - 21.3% of the population in Greater Malang is farmer.

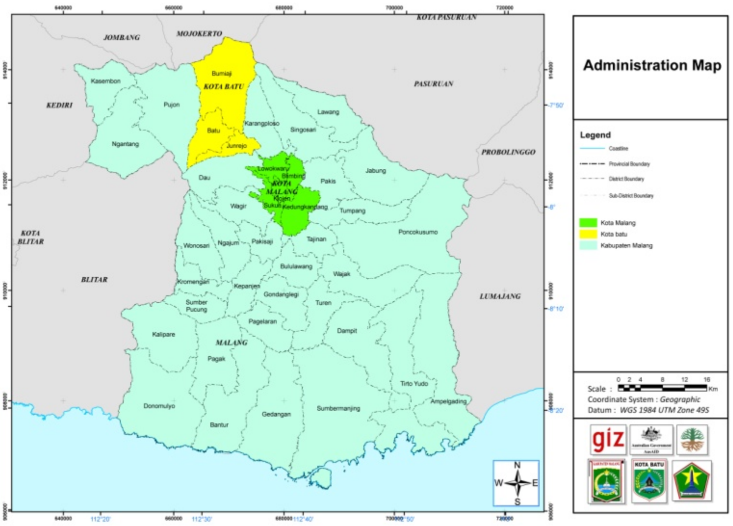

Figure 2.2 Administrative map of Sub-District

Table 2.1 Area of Sub-District in Greater Malang in 2010

Sub-District	**Area (ha)**	**Village/Ward**	**Agriculture Land (ha)**	**Wetland Agriculture (ha)**	**Dryland Agriculture (ha)**
01. Donomulyo	19,260	10	10,209	2,017	8,192
02. Kalipare	10,539	9	5,544	2,907	2,637
03. Pagak	9,008	8	5,489	530	4,959
04. Bantur	15,915	10	9,266	1,253	8,013
05. Gedangan	13,055	8	6,945	687	6,258
06. Sumbermanjing	23,949	15	8,651	849	7,802
07. Dampit	13,531	12	3,566	1,481	2,085
08. Tirtoyudo	14,196	13	3,964	499	3,465
09. Ampelgading	7,960	13	5,322	407	4,915
10. Poncokusumo	10,299	17	7,940	1,470	6,470
11. Wajak	9,456	13	5,130	1,486	3,644
12. Turen	6,390	17	4,183	2,434	1,749
13. Bululawang	4,936	14	3,738	1,960	1,778
14. Gondanglegi	7,974	14	4,747	3,245	1,502

Sub-District	Area (ha)	Village/Ward	Agriculture Land (ha)	Wetland Agriculture (ha)	Dryland Agriculture (ha)
15. Pagelaran	4,583	10	3,141	2,650	491
16. Kepanjen	4,625	18	3,360	2,399	961
17. Sumberpucung	3,590	7	2,147	1,873	274
18. Kromengan	3,863	7	2,807	1,707	1,100
19. Ngajum	6,012	9	4,240	1,692	2,548
20. Wonosari	4,853	8	1,650	920	730
21. Wagir	7,543	12	4,393	1,316	3,077
22. Pakisaji	3,841	12	2,617	1,817	800
23. Tajinan	4,011	12	3,052	1,752	1,300
24. Tumpang	7,209	15	4,205	1,505	2,700
25. Pakis	5,362	15	3,783	1,903	1,880
26. Jabung	13,589	15	4,653	1,224	3,429
27. Lawang	6,823	12	3,778	704	3,074
28. Singosari	11,851	17	4,370	1,560	2,810
29. Karangploso	5,874	9	3,298	1,328	1,970
30. Dau	4,196	10	2,736	486	2,250
31. Pujon	13,075	10	3,300	1,516	1,784
32. Ngantang	14,770	13	3,542	1,162	2,380
33. Kasembon	5,567	6	2,506	706	1,800
34. Kedungkandang	3,989	12	1,733	619	1,114
35. Sukun	2,097	11	718	322	396
36. Klojen	883	11	0	0	0
37. Blimbing	1,777	11	147	142	5
38. Lowokwaru	2,260	12	394	312	82
39. Batu	4,546	8	1,371	594	777
40. Junrejo	2,565	7	1,286	814	472
41. Bumiaji	12,798	9	2,362	1108	1,254
Greater Malang	**328,620**	**471**	**156,283**	**53,356**	**102,927**

Table 2.2 Total number of Greater Malang Resident in Each Sub-District in 2010

Sub-District	**Area (km^2)**	**Total Number of Resident**	**Population Density (per Km^2)**	**Total Number of Farmer**	**Proportion of Farmer (%)**
01. Donomulyo	192.6	73,047	379	15,883	0.217
02. Kalipare	105.4	67,045	636	14,453	0.216
03. Pagak	90.1	50,672	562	10,790	0.213
04. Bantur	159.2	71,294	448	15,315	0.215
05. Gedangan	130.6	55,079	422	11,846	0.215
06. Sumbermanjing	239.5	97,034	405	20,801	0.214
07. Dampit	135.3	117,348	867	25,083	0.214
08. Tirtoyudo	142.0	62,923	443	13,460	0.214
09. Ampelgading	79.6	57,537	723	12,241	0.213
10. Poncokusumo	103.0	93,117	904	19,767	0.212
11. Wajak	94.6	81,284	859	17,269	0.212
12. Turen	63.9	112,210	1,756	23,960	0.214
13. Bululawang	49.4	61,374	1,242	13,179	0.215
14. Gondanglegi	79.7	78,619	986	16,618	0.211
15. Pagelaran	45.8	66,125	1,444	13,997	0.212
16. Kepanjen	46.3	93,186	2,013	19,859	0.213
17. Sumberpucung	35.9	54,773	1,526	11,656	0.213
18. Kromengan	38.6	39,222	1,016	8,442	0.215
19. Ngajum	60.1	50,247	836	10,718	0.213
20. Wonosari	48.5	43,984	907	9,532	0.217
21. Wagir	75.4	76,592	1,016	16,274	0.212
22. Pakisaji	38.4	74,953	1,952	15,919	0.212
23. Tajinan	40.1	49,949	1,246	10,594	0.212
24. Tumpang	72.1	74,839	1,038	15,903	0.212
25. Pakis	53.6	123,034	2,295	26,026	0.212
26. Jabung	135.9	70,522	519	14,812	0.210
27. Lawang	68.2	91,358	1,340	19,344	0.212
28. Singosari	118.5	152,873	1,290	32,438	0.212
29. Karangploso	58.7	54,518	929	11,593	0.213
30. Dau	42.0	56,112	1,336	12,191	0.217
31. Pujon	130.8	61,618	471	12,982	0.211
32. Ngantang	147.7	58,015	393	12,415	0.214
33. Kasembon	55.7	31,069	558	6,606	0.213
34. Kedungkandang	39.9	162,941	4,084	6,605	0.041
35. Sukun	21.0	175,772	8,370	7,125	0.041
36. Klojen	8.8	127,415	14,479	5,165	0.041
37. Blimbing	17.8	171,935	9,659	6,969	0.041
38. Lowokwaru	22.6	182,794	8,088	7,409	0.041
39. Batu	45.5	97,881	2,151	13,432	0.137
40. Junrejo	25.7	50,447	1,963	5,592	0.111
41. Bumiaji	128.0	58,652	458	24,422	0.416
Greater Malang	**3,286.5**	**3,429,409**	**1,043**	**588,684**	**0.172**

Source: Bureau of Greater Malang 's Government 2010

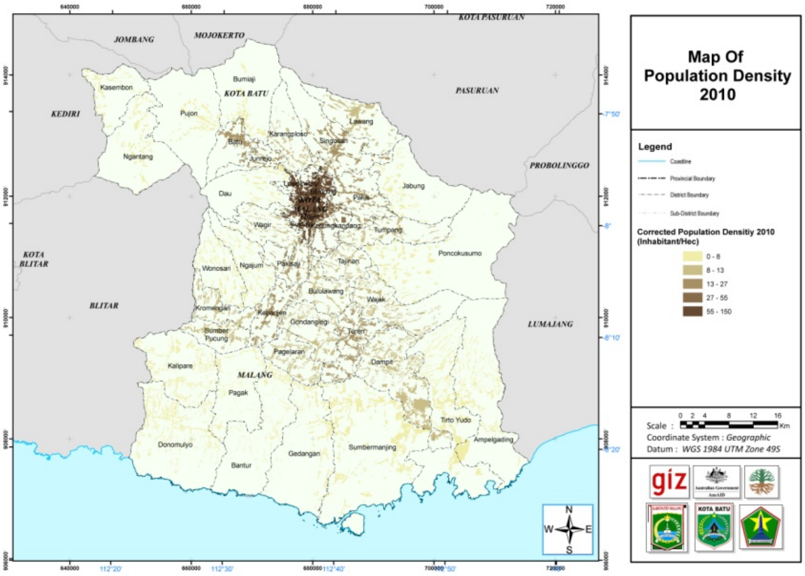

Figure 2.3 Population density map on sub-district administration 2010

The utilizations of agricultural land in Greater Malang are very diverse, that is Agricultural Wetlands (Farm), Dry land Agriculture (Field), Plantation, and Forest, River, Settlement, etc. (Table 2.3 and Table 2.4). Land area for agricultural activities covers 156.283 ha or 47.5% of the total area of Greater Malang. Agricultural land consists of wetlands (rice fields) covering an area of 53,356 ha (16.2%) and dry land (fields) covering an area of 102,927 ha (31.3%). The type of field in Greater Malang consists of irrigation, rainfed, and dryland as presented in Table 2.4.

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Table 2.3 Area and Proportion of Land Use in Greater Malang (2010)

Land Use		Total Area (ha)	Proportion (%)
1	Wetland Agriculture (Farm)	53,356	16.2
2	Dryland Agriculture (Field)	102,927	31.3
3	Plantation	19,578	6.0
4	Forest	8,196	2.5
5	Non Agriculture Land	71,646	21.8
6	Rivers, Settlements, Roads, etc.	72,917	22.2
Total		328,620	100.00

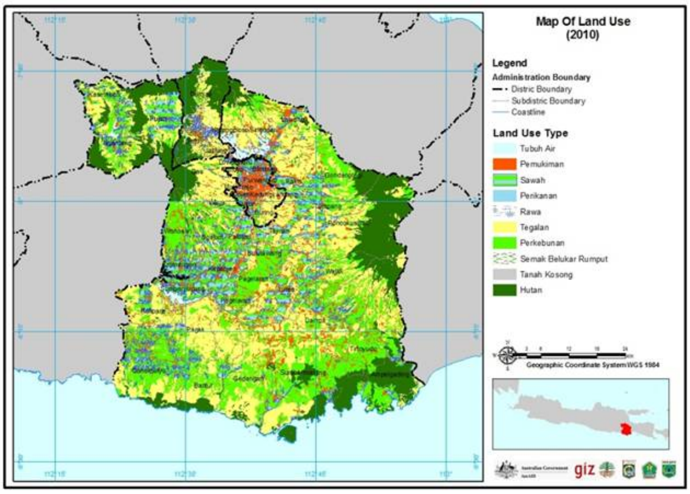


Figure 2.4 Land Use in Greater Malang 2010

Mountainous topography and hilly conditions make the area of Greater Malang as the cool area and in great demand as a residence and resting place. Based on monitoring results of three Climatology station post-monitoring, Karangploso-Malang, in 2010 the average air temperature is relatively low, ranging between 22.1 ^{o}C to 26.8 ^{o}C. The average humidity ranges from 69.0 percent to 87.0 percent and the variation of rainfall ranging from 4 mm to 727.0 mm per month. Rainy season usually occurs from October until April. The average of rainfall ranges is 2354 mm per year. The highest rainfall usually occurs in December or January, while the dry season usually starts from June until September.

Change of rainfall patterns are often occurs in Greater Malang, but in the period from 1981 to 2010 rainfall occurs in June,July, August, and September. There is also slight change in the air temperature, although in general, the pattern of temperature is spreading throughout the year. The pattern of rainfall and air temperature in Greater Malang is shown in Figure 4.2.

Table 2.4 Topology and Farming Area in Greater Malang in 2010 (ha)

Sub-District	Type of Field			Total of Farm Area (ha)
	Irrigation (ha)	Rainfed (ha)	Dryland (ha)	

Sub-District	**Type of Field**			**Total of Farm Area (ha)**
	Irrigation (ha)	**Rainfed (ha)**	**Dryland (ha)**	
01. Donomulyo	536	1,481	8,192	10,209
02. Kalipare	0	2,907	2,637	5,544
03. Pagak	0	530	4,959	5,489
04. Bantur	246	1,007	8,013	9,266
05. Gedangan	0	687	6,258	6,945
06. Sumbermanjing	197	652	7,802	8,651
07. Dampit	445	1,036	2,085	3,566
08. Tirtoyudo	165	334	3,465	3,964
09. Ampelgading	172	235	4,915	5,322
10. Poncokusumo	925	545	6,470	7,940
11. Wajak	861	625	3,644	5,130
12. Turen	2,088	346	1,749	4,183
13. Bululawang	1,960	0	1,778	3,738
14. Gondanglegi	2,964	281	1,502	4,747
15. Pagelaran	2,430	220	491	3,141
16. Kepanjen	2,390	9	961	3,360
17. Sumberpucung	1,873	0	274	2,147
18. Kromengan	1,707	0	1,100	2,807
19. Ngajum	775	917	2,548	4,240
20. Wonosari	104	816	730	1,650
21. Wagir	1,040	276	3,077	4,393
22. Pakisaji	1,817	0	800	2,617
23. Tajinan	936	816	1,300	3,052
24. Tumpang	1,316	189	2,700	4,205
25. Pakis	1,803	100	1,880	3,783
26. Jabung	1,168	56	3,429	4,653
27. Lawang	447	257	3,074	3,778
28. Singosari	1,330	230	2,810	4,370
29. Karangploso	1,146	182	1,970	3,298
30. Dau	321	165	2,250	2,736
31. Pujon	771	745	1,784	3,300
32. Ngantang	687	475	2,380	3,542
33. Kasembon	323	383	1,800	2,506
34. Kedungkandang	619	0	1,114	1,733
35. Sukun	322	0	396	718
36. Klojen	0	0	0	0
37. Blimbing	142	0	5	147
38. Lowokwaru	312	0	82	394
39. Batu	587	7	777	1,371
40. Junrejo	801	13	472	1,286
41. Bumiaji	1,098	10	1,254	2,362
Greater Malang	**36,824**	**16,532**	**102,927**	**156,282**

Source: Bureau of Greater Malang 's Government 2010

The productivity of crops in Greater Malang is correlated with rainfall patterns because the source of irrigation water comes from rains. Average annual rainfall varies according to season and region. About 80% of annual rainfall occurs between October and February. The period between June and September is really dry and only produce less than 10% of annual rainfall.

Greater Malang, which has two seasons; the rainy and dry seasons, is closely related to the location of this island which is near the equator and between two continents, Asia and Australia, and also between two oceans, Indian and Pacific Oceans. The beginning and the end of rainy season in Greater Malang are highly uncertain. Sometimes rainy season occurs from October until April, but the starting and ending time varies depend on its location and natural phenomena. The dry season occurs from June until September. When coincided with the El Niño phenomena, droughts usually occur in Greater Malang which is marked by the rainy season starting in mid-November and even in early December. The type of climate in the region of Greater Malang is C3 by 6 to 8 months of wet and 1 to 3 months of drought per year (Oldeman, 1975) as shown in Table 4.**2**.

The onsets of rainy and dry season in Greater Malang are crucial to determine the starting time of planting and harvesting seasons. In the irrigated and rainfed land in Greater Malang there are two cropping seasons in a year, that is (1) Planting Season I, which is called the Rainy Season (RS), occurs from October to March, farmers usually plant rice in this season, (2) Planting Season II, which is called the Dry Season I (DS), occurs from April to September, in this season farmers usually plant paddy in technically irrigated lands and dry crops (Palawija) in non-irrigated lands. In detail, the cropping pattern in Greater Malang is listed in Table 2.5.

Table 2.5 Alternative of Annual Crop Patterns in Greater Malang

Land Type	Crop Patterns in Greater Malang											
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**
Irrigation	Paddy			Palawija			Fallow			Paddy		
Rainfed	Paddy		Palawija			Fallow			Palawija			🟩

F: Fallow (Bera)

Those cropping patterns are the farmers' habit and routine activities every year. If the rain begins to fall in October, the farmers who apply the irrigated land system begin to sparse rice seeds. While in the rainfed lowland rice systems they prefer to plant *Gogorancah* (*Gora*). The production level of paddy in Greater Malang, both farm-paddy (scaffolding) and Gora, is very determined by the rainfall patterns and pest attacks. Achievement of this production is not only caused by low rainfall at planting time or during rice growth (e.g. during primordial), but it is also determined by rainfall at the time of panicle discharge (flowering). If very excessive rainfall occurs during flowering, then the production will be low because of incomplete pollination. Rainfall fluctuation in Greater Malang is causing harvest and crop failures, which is the hazard of climate change. Therefore, the vulnerability assessment of climate change adaptation is conducted in Greater Malang.

2.2 Potential of Agriculture Resource in Greater Malang

As in Indonesian economy, agriculture is the main economic potential of Greater Malang after oil and gas. The majority livelihoods of the population in this relies in agriculture business, from food crops, plantations, farms to fishing. Revitalization of agriculture that was stated by the government on RPJMN 2004 - 2009, would be incentive for the government and residents of Greater Malang to seriously develop agricultural sector in this region. In connection with the revitalization of agriculture, fisheries and national forestry, Greater Malang, as one of the main producers of agricultural products, have a strategic role that must be done to promote agricultural development in order to increase farmers' income and welfare of other related economic actors. The role of Greater Malang, as other areas in Java, is increasingly important in producing agricultural products, other than plantation commodities, livestock, and fisheries.

The decreasing of agricultural land especially for paddy in Java Island, while demand for rice continues to increase along with population growth, so the efforts to achieve progress in the agricultural sector in Greater Malang have been shown seriously by all stakeholders in this area.

Policy development of food security is directed to fulfil the requirements of food’s quality, safe, equitable and affordable, and to accelerate the diversification of production and consumption of food. The development of food security itself faces the issue of availability, distribution and consumption. The quality of outcomes and productivity is still low because not all food commodities that are produced can fulfil self-production. Food availability and distribution are not uniform over time and among regions. Food surplus occurs when harvesting time (staple food) from February to May (± 70%), while food deficit occurs in the remaining months.

Great harvest in Greater Malang only occurs in the central sub-district, mainly Dampit, Turen, Kepanjen, and Singosari, while limited quantities of foods occur in other sub-districts. Furthermore, farmers in Greater Malang have tradition to sell their crops directly and there is a tendency to change the functions of production lands.

Farming capital in Greater Malang is still limited. This condition led to the lower level of the average of food crops and horticulture productivity than the average of national productivity. As consequence, farmers could not buy the recommended technology of production facilities. Many agricultural extension workers change their jobs due to the emergence of new district and city as a result of regional divisions. As a consequence, shortage of agricultural extension worker occurs in village. This condition delays the transfer of technology and agricultural science to farmers. Great harvest which occurs in the month with a high level of rainfall causing difficulties for farmers to dry the grain so the grain quality is lower. On the other hand, the limited number of dryers causing the sale value of rice/paddy is low. Furthermore, community participation to improve the quality and food safety, both as producers and consumers, is lack. Attempts to optimize land use, improving product quality and lack of manpower availability to farming depend on the role of agricultural tools and machines which can speed up the time to process the land, drying and processing the results in order to improve the quality of results.

After harvest, usually farmers do not store their grain in groups, so that the empowerment of communities through the development of barns still have problem. Mastery of farmers to capital, markets and technologies that are limited causing stunted farmers' welfare improvement. Quality and low workforce skills become serious obstacles that impede the progress in agriculture.

One of the development agenda in Greater Malang is to bring Greater Malang as the East Java Province barns. One of the fundamental goals of this agenda is to improve primary food production such as rice, corn, and others and to contribute more significantly to fulfil East Java food requirement with the potential of land and existing human resources in Greater Malang. This goal also includes increased production of other food products from the fisheries, livestock and plantations sub-sectors that will help to fulfil the food requirements in Eas Java Province.

In addition to the interests of the consumer society, programs and activities, increase in production is expected to rising incomes and social welfare of farmers and other economic actors fairly. Therefore, government's efforts to suppress the level of unemployment by increasing labour absorption or opening new jobs, reduce poverty and/or increase public revenue, and enhance national economic growth will realize.

2.2.1 Paddy

In Greater Malang, rice is planted in the wetlands and drylands. Wetlands include paddy rainfed and irrigated field. Almost all sub-districts in Greater Malang produce rice. Dampit, Turen, Kepanjen, and Singosari Sub-district becomes the largest producer of paddy with harvest area covering 15,727 hectares. In 2010, Greater Malang has harvest area of 66,047 ha with production of 441,567 tons.

In general, the average value of production per hectare of wetland paddy is larger than the dryland paddy. This is due to better and more regular irrigation of wetland paddy than dryland paddy. In 2010, average production per hectare of wetland paddy is 6.53 ton per hectare, while the average production of dryland paddy is only 4.55 ton per hectare (Government of Greater Malang, 2010). In general, the productivity per ha of wetland and dryland paddy in 2010 can be seen in Table 2.6 and Figure 2.5 and Figure 2.6.

In irrigated fields, paddy can be planted two times per season, while in rainfed is only once. Rainfed land with area of **16,532** ha can be developed into irrigated land supported by irrigation infrastructure rehabilitation/drainage, micro-watersheds, development of machinery (hand tractors and water pumps), use of improved seed (early maturing varieties), fertilization, counselling and assistance (Government of Greater Malang, 2010).

Cropping pattern which is evolving in the peasant society of Greater Malang is based on nationally applied cropping pattern by following the distribution pattern of rainfall. Most of the irrigated land has been cropped with cropping index (IP) of 200, once at the beginning of the rainy season (harvest from December to February) and once at the end of rainy season (harvest from March to May). Cropping systems are conducted simultaneously, either when planting or harvest. This is done to ease the setting of water system, mentoring by field officers and controlling pests and disease that may arise (Subowo Gito, 2008). Planting corn is done in September and then prepare for the next rice planting.

Potential dryland areas in Greater Malang are reaching 102,927 hectares or 31.3% of the total area of Greater Malang. However, their utilization is not optimal. Several locations in the dryland of Greater Malang shows that one of the success factor in agro ecosystem rice farming lies in the use of high yielding varieties and appropriate planting time. All of these systems depend on the season condition or water availability.

Table 2.6 Harvesting area, Productivity, and Paddy Production in Greater Malang in 2010

Sub-District	Wetland Paddy			Dryland Paddy		
	Harvesting Area (ha)	Productivity (ton/ha)	Production (ton)	Harvesting Area (ha)	Productivity (ton/ha)	Production (ton)
01. Donomulyo	2,575	6.09	15,673	467	4.59	2,145
02. Kalipare	1,946	6.4	12,445	1,204	4.59	5,526
03. Pagak	230	6.07	1,395	715	4.67	3,341
04. Bantur	1,716	6.09	10,448	500	4.59	2,294
05. Gedangan	727	6.09	4,429	129	4.49	579
06. Sumbermanjing	922	6.39	5,889	20	4.36	87
07. Dampit	4,109	6.47	26,588	1,632	4.86	7,929
08. Tirtoyudo	875	6.1	5,336	440	4.88	2,145
09. Ampelgading	601	5.93	3,562	0	0	0
10. Poncokusumo	1,284	6.08	7,805	3	4.28	13
11. Wajak	963	7.77	7,488	185	5.15	954
12. Turen	3,072	8.01	24,606	27	4.59	124
13. Bululawang	1,273	6.18	7,861	8	4.7	38
14. Gondanglegi	1,147	8.57	9,833	0	0	0
15. Pagelaran	2,226	8.75	19,481	0	0	0
16. Kepanjen	3,683	8.07	29,734	0	0	0
17. Sumberpucung	2,475	7.62	18,864	0	0	0
18. Kromengan	2,783	6.04	16,793	0	0	0
19. Ngajum	1,935	6.47	12,529	99	4.28	424
20. Wonosari	919	6.1	5,606	9	4.04	36
21. Wagir	910	6.18	5,618	73	4.18	305
22. Pakisaji	2,176	6.48	14,702	0	0	0
23. Tajinan	1,707	5.81	9,918	6	3.83	23
24. Tumpang	1,450	6.15	8,917	0	0	0
25. Pakis	2,083	7.76	16,157	0	0	0
26. Jabung	2,127	6.18	13,135	130	4.07	529
27. Lawang	1,484	7.53	11,171	0	0	0
28. Singosari	2,904	8.39	24,365	300	6.26	1,877
29. Karangploso	2,547	6.34	16,157	39	4.81	187
30. Dau	264	6.22	1,646	24	4.14	99
31. Pujon	173	5.56	963	0	0	0
32. Ngantang	1,475	6.14	9,050	0	0	0
33. Kasembon	1,675	6.03	10,105	18	4.13	74
34. Kedungkandang	600	6.76	4057	0	0	0
35. Sukun	673	7.77	5226	0	0	0
36. Klojen	0	0.00	0	0	0	0
37. Blimbing	209	7.07	1477	0	0	0
38. Lowokwaru	643	6.85	4405	0	0	0
39. Batu	344	6.45	2220	0	0	0
40. Junrejo	472	6.45	3042	0	0	0
41. Bumiaji	642	6.45	4141	0	0	0
Greater Malang	**60,019**	**6.53**	**412,838**	**6,028**	**4.55**	**28,729**

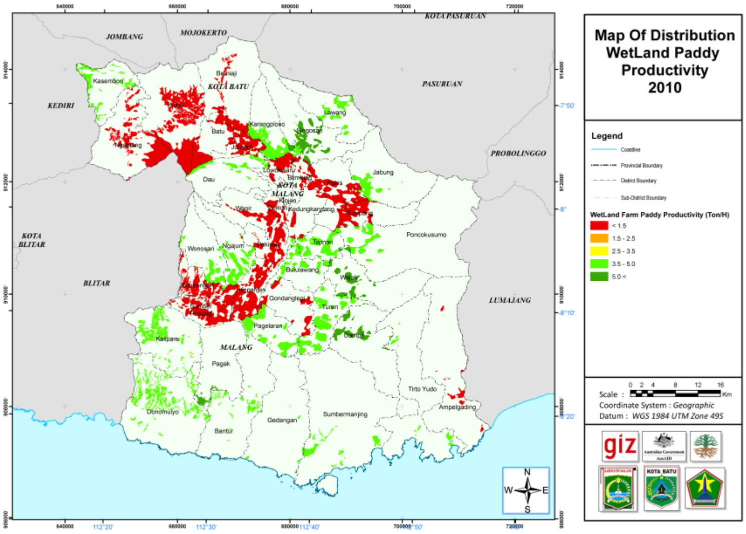


Figure 2.5 Distribution of Wetland Paddy Productivity in Greater Malang

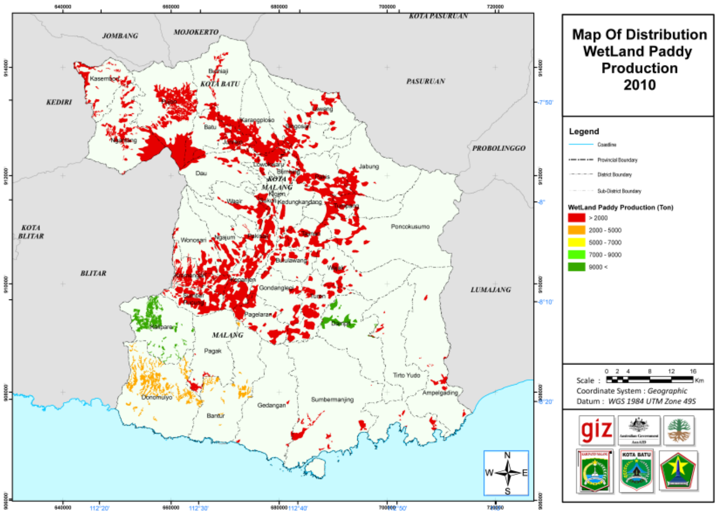


Figure 2.6 Distribution of Wetland Paddy Productions in Greater Malang

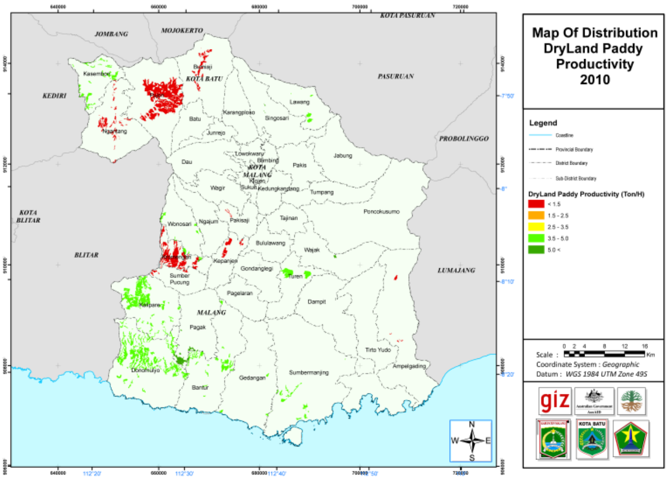


Figure 2.7 Distribution of Dryland Paddy Productivity in Greater Malang

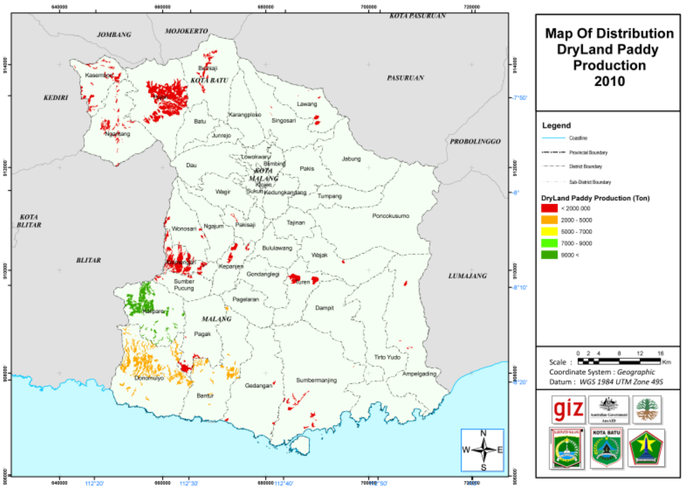


Figure 2.8 Distribution of Dryland Paddy Productions in Greater Malang

In dryland filed uses "gogo system", planting is done in the rainy season, if sufficient water is available. The main obstacle to develop dryland field is biophysical factors, institutional infrastructure, and supporting facilities. Cultivation technology that is used is the use of high yielding varieties that are adaptive in dryland areas, timeliness of planting, fertilizing and pest control/ disease. The application of rice farming technology (introduction) appeared to increase yields and incomes of farmers in dryland wetlands. The development of large-scale farming technology (overlay) needs the support of various parties including financial institutions, *saprodi* providers, counselling, active participation of farmers and government policy.

2.2.2 Corn

In Greater Malang, corns are produced in dryland. The corn crop is usually grown in paddy fields in the third growing season (from September to November), after the rice harvest. Generally, corn is cultivated by monoculture farming, but some are grown intercropped with other crops, such as soybeans. On the dryland, corn is plant by monoculture farming. Some are planted with other crops, such as pepper. On dryland, corn can be harvested 3 times (planting pattern of corn-corn-corn or corn-corn-soybean).

Maintenance is an important factor for the sustainability of corn production, particularly pest and disease control. After harvest, corn is processed into dry looses, and processed further into flour, or send to corn processing factory unit and processed into animal feed (Bappeda Malang, 2010). Maize production in Greater Malang in 2010 has reached **290,124** ton, while productivity of maize is 4.53 tons per ha (Table 2.7).

Donomulyo, Kalipere, Sumbermanjing, Bantur, Gedangan, Poncokusumo, Wajak, Turen, Dampit, Wagir, Tajinan, Jabung, and Kasembon Sub-district becomes the largest producer of corn with land area covering 4,394 hectares and production reaching 197,664 ton.

Table 2.7 Harvested Area, Productivity, and Corn Productions in Greater Malang in 2010

Sub-District	Corn		
	Harvested Area (ha)	Productivity (kw/ha)	Production (ton)
01. Donomulyo	467	4.09	7,741
02. Kalipare	1,204	4.18	23,881
03. Pagak	715	4.57	5,252
04. Bantur	500	4.20	11,715
05. Gedangan	129	4.16	11,892
06. Sumbermanjing	20	4.23	7,652
07. Dampit	1,632	4.20	24,101
08. Tirtoyudo	440	4.34	6,358
09. Ampelgading	0	4.15	1,403
10. Poncokusumo	3	5.54	14,598
11. Wajak	185	5.02	50,888
12. Turen	27	6.08	12,245
13. Bululawang	8	4.92	1,018
14. Gondanglegi	0	6.50	1,450
15. Pagelaran	0	6.12	3,007
16. Kepanjen	0	5.68	312
17. Sumberpucung	0	6.90	9,671
18. Kromengan	0	4.39	641
19. Ngajum	99	5.43	2,706
20. Wonosari	9	4.90	2,145
21. Wagir	73	4.22	6,986
22. Pakisaji	0	4.83	207
23. Tajinan	6	4.84	10,769
24. Tumpang	0	4.70	10,267
25. Pakis	0	6.08	2,706
26. Jabung	130	4.94	7,191
27. Lawang	0	4.43	4,698
28. Singosari	300	5.16	3,658
29. Karangploso	39	4.40	3,037
30. Dau	24	4.83	5,409
31. Pujon	0	5.18	8,993
32. Ngantang	0	5.21	8,472
33. Kasembon	18	4.89	8,005
34. Kedungkandang	0	3.54	1069
35. Sukun	0	3.52	74
36. Klojen	0	0.00	0
37. Blimbing	0	0.00	0
38. Lowokwaru	0	3.55	103
39. Batu	0	3.96	3042
40. Junrejo	0	3.96	1850
41. Bumiaji	0	3.96	4912
Greater Malang	**61,418**	**4.53**	**290,124**

2.3 Hazard and Vulnerability of Agriculture Sector

The agricultural sector is one of the sectors that very open to climate change and variability. Planning and agricultural activities depends on climatic conditions. Planning of planting time, planting patterns, and selection of plant species must be adjusted to the climate. Likewise, agricultural activities ranging from land preparation, planting, maintenance, harvesting up to post-harvest are strongly influenced by the climate.

Climate change is characterized by rising air temperatures, intensity and distribution change of rainfall patterns, increase of intensity and frequency of extreme climate phenomena, and rising sea levels has negatively impact for the agricultural sector. Climate change hazards will clearly impinge some aspects of agricultural activities such as planting, irrigation water use, harvesting, and others. Therefore, crop failures, harvest failures, and reduced crop yields is the hazards of climate change on agriculture. Other hazards are the decline in agricultural land in lowland or coastal areas due to the increase of sea levels.

The impact of climate change is very dangerous because Greater Malang is dominated by dryland farming systems where water management is very difficult and influenced by the climate change. Even the impact of climate change will be more serious because 47.5% of the area of Greater Malang is for agricultural activities. Climate change hazards in the form of harvest failure, crop failure, and decreased of crop yields will decrease the agricultural production. The decline in production was in turn will interfere with the availability and food security in Greater Malang. Thus, climate change hazards have harm influence to the food barns program of the government of Greater Malang and disrupt the national food supply in Greater Malang which donates almost 441,567 tons of rice per year.

Greater Malang has tropical climate with two seasons, the rainy season and dry season. Although the duration of rainy season is relatively longer than the dry season, the start of the rainy season each year is usually uncertain, and therefore contributes to the agricultural sector, especially the planting season and planting schedule. The type of soil and land use, topography (slope), population of each district, the frequency and distribution of rainfall, and the level of poverty population in Greater Malang is relatively diverse. Therefore, these factors greatly affect the vulnerability of the agricultural sector in Greater Malang.

Vulnerability to climate change in Greater Malang highly depends on the extent of climate change that hit the farming system, the extent of sensitivity of agricultural land types, agricultural prosperity, and population, and the ability of the agricultural sector stakeholders in Greater Malang to adapt (adaptive capacity) to climate change. Adaptive capacity is largely influenced by the level of education, income, population, access to capital, and the availability of irrigation infrastructure in Greater Malang.

Greater Malang has fairly extensive agricultural land and the majority of Greater Malang's residents are farmers who are very vulnerable to climate change. In addition, because most of their agricultural land is dry land, the welfare of farmers is still quite low, and the population is high (**3,429,409** people). On the other hand, the low level of education, income, population, access to capital, and irrigation infrastructure in Greater Malang will become barriers to adapt to climate change. Thus, it is very difficult to reduce vulnerability to climate change on agriculture in Greater Malang.

2.4 Strategic Issues in Agriculture Sector: Climate Change and Development

One of the strategic issues in Greater Malang is the effort to bring Greater Malang as the Granary of Food through the revitalization of agriculture. Another issue related to the agricultural sector is the disaster-prone (floods and landslides) of Greater Malang area. Revitalization of agriculture is the local government efforts to suppress the level of unemployment by increasing labour absorption or opening new jobs, alleviate poverty and/ or increase public revenue, and enhance economic growth.

In general, the problems that is need to be solved in the efforts of agricultural development to succeed the food barns program are (1) the availability and condition of transportation infrastructure, (2) the difficulty faced by farmers and agricultural entrepreneurs to obtain agricultural credit, (3) lack of agricultural extension activities, (4) limited number and/or availability of *saprodi* in the field, such as fertilizers, (5) has many old annual plants (apple), (6) uncertainty of land rights, (7) many irrigations are damaged and poorly maintained, and (8) lack of the development of agricultural production as part of efforts to increase value-added products that can be enjoyed by farmers and agricultural entrepreneurs.

Development of barns as efforts to achieve food security is not just focused on providing food, but also covers issues of accessibility which is characterized by the purchasing power of individuals and society. Greater Malang Food Barn has a broader meaning, that is Greater Malang is not only as the manufacturers/ suppliers and providers of food reserves and other agricultural products in fresh form as well as the results of agro-industry, where the food is sufficient to be consumed by society, but also have the purchasing power and convenience to access the food that has stable food security and earn decent income level to cover other necessities of life.

Various implementations of agricultural programs in Greater Malang depend on the effects of climate change. The success or failure of implementation of the development of agricultural sector is highly influenced by climate. Therefore, the implementation and planning of agricultural development should mainstream the impacts of climate change.

There are several findings in the field that relevant to the climate change on agricultural sector in Greater Malang, that is:

1. Higher intensity and sporadic rainfall often causes flooding of agricultural land and crop failure especially on wetlands paddy field. However, rainfall is concentrated in a few months of the year and few rainfalls in the remaining months, so prone to drought, especially in drylands, such as Donomulyu, Bantur, Gedangan, Sumbermanjing, Pagak, Ampelgading, and Pancokusumo Sub-Districts.
2. The beginning of rainy and dry season has change so farmers are very difficult to determine the initial planting, especially on dry land and rainfed, such as Donomulyu, Bantur, Gedangan, Sumbermanjing, Pagak, Ampelgading, and Pancokusumo Sub-Districts.

3. The rainy season shift into shorter period thus causing brief time of planting season. As a result, farmers tend to prefer short-lived crops (*palawija*), such as in Donomulyu, Bantur, Gedangan, Sumbermanjing, and Pancokusumo Sub-Districts.
4. The availability of water resources for agricultural land has changes and fewer so triggering the conversion of agricultural lands into non-agricultural lands such as in Kedungkandang, Sukun, Blimbing, Lowokwaru, Batu, Junrejo, and Bumiaji Sub-District.

Assessment of agricultural sector in Greater Malang could not be separated from the development planning, especially Spatial Planning that has been being developed by the Greater Malang Government recently for the time span 2010 – 2030. Spatial Pattern Map is developed under the framework of the Spatial Plan (see **Error! Reference source not found.**).

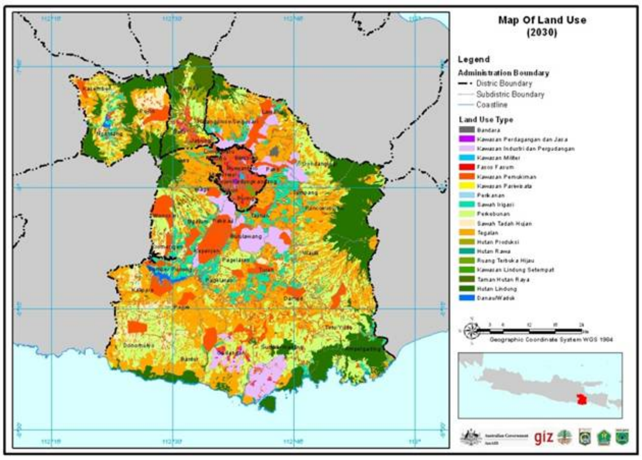


Figure 2.9 Land use map 2030 of Greater Malang according to Spatial Pattern of RTRW (Source: GIS team)

This development plan also refers to the demographic population that is projected into the time frame of this assessment as well as of the spatial planning, i.e. 2030 (see Table 2.8and **Error! Reference source not found.**). Population projection of each sub-district in Greater Malang in 2030 is calculated based on population growth rate of Greater Malang between 2000 and 2010, which is **2** % per year.

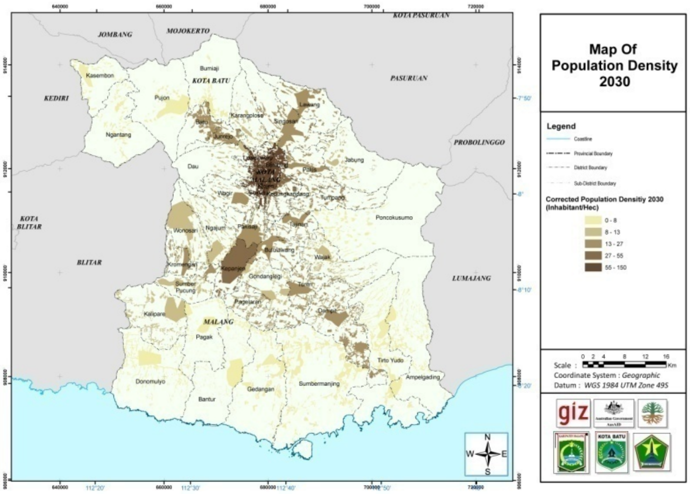


Figure 2.10 Population density map of 2030

Table 2.8 Projected population and farmer for each sub-district in 2030

Sub-District	Area (km^2)	Total Number of Resident	Population Density (per Km^2)	Total Number of Farmer	Proportion of Farmer (%)
01. Donomulyo	192.6	118,855	617	25,843	0.217
02. Kalipare	105.4	99,617	945	21,475	0.216
03. Pagak	90.1	75,122	834	15,996	0.213
04. Bantur	159.2	105,872	665	22,743	0.215
05. Gedangan	130.6	75,560	579	16,251	0.215
06. Sumbermanjing	239.5	140,892	588	30,203	0.214
07. Dampit	135.3	175,207	1,295	37,450	0.214
08. Tirtoyudo	142.0	94,308	664	20,174	0.214
09. Ampelgading	79.6	85,014	1,068	18,087	0.213
10. Poncokusumo	103.0	127,702	1,240	27,109	0.212
11. Wajak	94.6	125,670	1,328	26,699	0.212
12. Turen	63.9	162,295	2,540	34,655	0.214
13. Bululawang	49.4	90,470	1,831	19,427	0.215
14. Gondanglegi	79.7	80,121	1,005	16,936	0.211
15. Pagelaran	45.8	98,889	2,159	20,932	0.212
16. Kepanjen	46.3	181,283	3,915	38,634	0.213
17. Sumberpucung	35.9	39,762	1,108	8,461	0.213
18. Kromengan	38.6	58,195	1,508	12,526	0.215
19. Ngajum	60.1	73,402	1,221	15,657	0.213
20. Wonosari	48.5	68,230	1,407	14,787	0.217
21. Wagir	75.4	108,633	1,441	23,082	0.212
22. Pakisaji	38.4	110,763	2,884	23,525	0.212
23. Tajinan	40.1	72,188	1,800	15,311	0.212
24. Tumpang	72.1	110,484	1,532	23,478	0.212
25. Pakis	53.6	169,905	3,170	35,941	0.212
26. Jabung	135.9	103,319	760	21,700	0.210
27. Lawang	68.2	138,176	2,026	29,257	0.212
28. Singosari	118.5	217,268	1,833	46,102	0.212
29. Karangploso	58.7	83,014	1,414	17,652	0.213
30. Dau	42.0	84,696	2,017	18,401	0.217
31. Pujon	130.8	93,352	714	19,668	0.211
32. Ngantang	147.7	83,567	566	17,883	0.214
33. Kasembon	55.7	44,879	806	9,542	0.213
34. Kedungkandang	39.9	222,011	5,564	8,999	0.041
35. Sukun	21.0	202,131	9,625	8,193	0.041
36. Klojen	8.8	125,321	14,241	5,080	0.041
37. Blimbing	17.8	197,910	11,119	8,022	0.041
38. Lowokwaru	22.6	231,226	10,231	9,372	0.041
39. Batu	45.5	98,706	2,169	16,355	0.137
40. Junrejo	25.7	50,872	1,979	6,788	0.111
41. Bumiaji	128.0	59,147	462	30,584	0.416
Greater Malang	**3,286.5**	**4,684,036**	**1,425**	**838,978**	**0.172**

Chapter III Methodology of Vulnerability and Risk Assessments, and Adaptation of Climate Change on Agricultural Sector in Greater Malang

3.1 Vulnerability Conceptual Framework

The second Intergovernmental Panel on Climate Change (IPCC) Assessment Report (SAR) defines vulnerability as the extent to which climate change could damage or compromise the system, so it does not only depend on the sensitivity of the system, but also in its ability to adapt to new climate conditions. The third IPCC Assessment Report (TAR) describes the vulnerability components, by defining it as: "The extent to which a system is susceptible or unable to cope with the adverse impacts of climate change including climate variability and extreme climate. Vulnerability is the function of character, magnitude, and the level of climate variation described by the exposure components, sensitivity and adaptive capacity. According to this definition, vulnerability includes an external dimension which is represented by the exposure system to climate variations, as well as the internal dimension which is more complex and consists of sensitivity and adaptive capacity to stress (Füssel and Klein 2006) . The fourth IPCC Assessment Report (AR4) states that a highly vulnerable system is very sensitive to climate change, where the sensitivity includes the potential effects of hazards and limited adaptability.

Luers et al. (2003) propose a method to measure the vulnerability which is based on three components: exposure, sensitivity and adaptive capacity. Turner et al. (2003) recognizes that the vulnerability is not only determined by the hazard (interference and voltage), but also depends on the sensitivity and resilience of the system that experiencing such hazards. Those authors developed a conceptual framework for integrated vulnerability that is built on three major dimensions of vulnerability: the exposure, sensitivity and adaptive capacity. Thus, vulnerability can be understood as a function of three components: exposure, sensitivity and adaptive capacity, which are influenced by various biophysical and socio-economic factors (TERI 2003).

Three dimensions of vulnerability. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as a function of the magnitude, character, and the rate of climate variation of a system affected by exposure, sensitivity, and adaptive capacity. More succinctly, the vulnerability is defined as having three components: exposure, sensitivity and adaptive capacity (Figure 3.1).

Exposure. Exposure is used to describe the biophysical impacts of climate change on agro-ecological systems (Tubiello and Rosenzweig, 2008). Exposure to the agricultural sector includes the spatial and temporal dimensions of the impact of climate variability and change, such as increased temperature, drought and torrential rain, and also the magnitude and duration of extreme weather events. Variability and climate change have large impact on agricultural land and the number of farmers in one place. Therefore, in this vulnerability assessment, agricultural land area and the number of people who work in agriculture sector are used as an indicators of exposure.

Sensitivity. Sensitivity is defined as the degree of system to be influenced by the climate change, whether adverse or profitable, and refers to the ability of agro-ecological systems to withstand the impact without any effort to adapt. Sensitivity is a complex concept because the system’s response can be influenced by the intrinsic characteristics and the degree of external interference, such as the type of agricultural land, farmers' income, labour composition, topography, and others. In the vulnerability assessment of agricultural sector, the type of agricultural land, farmers' income and the composition of the workforce are used as the sensitivity indicators.

Adaptive Capacity. The third dimension of vulnerability is the adaptive capacity, which is defined as the ability of institutions and individuals to avoid potential damage, to take advantage of opportunities, or to overcome due to the change. It is the most difficult aspects of vulnerability due to many socio-economic variables determine the adaptive capacity. Indicators, such as poverty, access to credit, education level, population and income can be used to measure the adaptive capacity. At farm level, farmers' adaptive capacity is influenced in part by knowledge and access to technology and also the extent to which farmers and other stakeholders to mobilize and gain access to resources, fertilizers and irrigation (irrigation). In this study, irrigation network, level of education, and income of the population are used as an indicators of adaptive capacity.

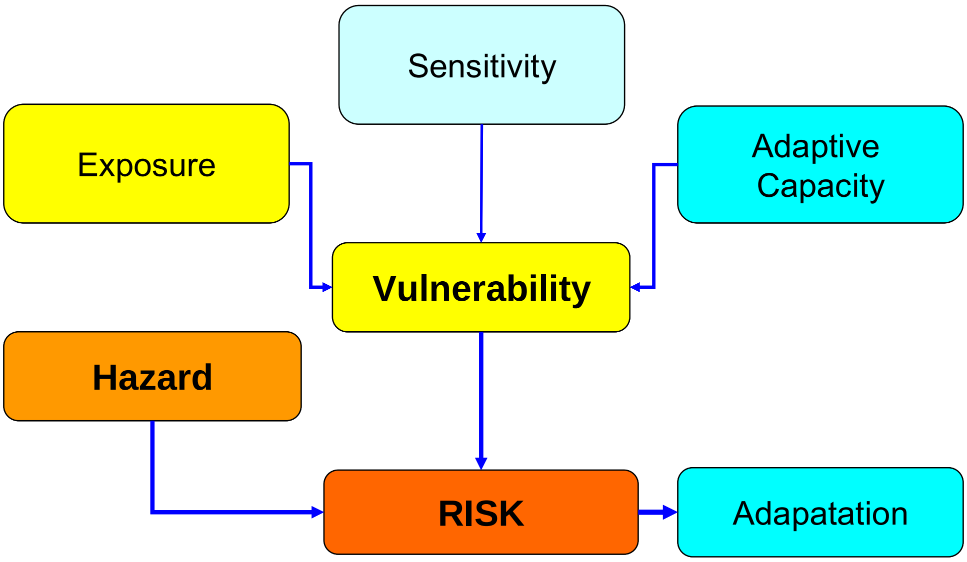


Figure 3.1 Framework of Vulnerability Assessment of Climate Change on Agricultural Sector

3.2 Assumption of Climate Change Tendency

The study of Intergovernmental Panel on Climate Change-IPCC (2007) suggested climate change with an increase in global average temperature (an increase of 0.76° C from 1899 to 2005); global average rise of sea level (average rate of 1,8 mm per year in the period between 1961 and 2003); increase of the uncertainty and intensity of rainfall, increased flooding, drought and erosion, and increasing extreme weather phenomena, such as El Nino, La Nina, cyclone, tornado, and hailstone.

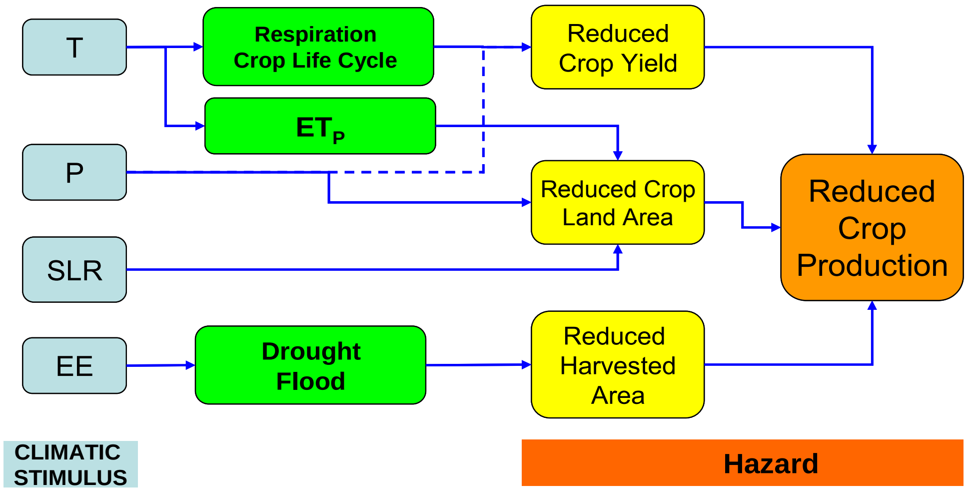
In this assessments of vulnerability and risk, as well as climate change adaptation in the agricultural sector use the assumption that climate change has been and continues to occur in Greater Malang which is the trigger (stimuli) of catastrophic events (hazard), such as:

1) Increasing of the average air temperature

2) Changes in rainfall patterns, both in intensity and periods of rainfall

3) Extreme weather events in the form of El-Nino and La-Nina

Those climatic stimuli have impact on the crop physiological processes, and furthermore, on the production of food crops, either directly or indirectly (Figure 3.2).



T : Temperature,
EE : Extreme Event,
SLR : Sea Level Rise,
P : Precipitation,
ETp : Potential Evapotranspiration

Figure 3.2 Framework of climatic stimuli analysis and hazard potency of climate change on agricultural sector

Vulnerability, risk, and adaptation assessment of climate change on agriculture in Greater Malang is a Meso Level Study which examines the phenomena and the vulnerability of the agricultural sector to climate change. The study focuses on analyzing the impact of climate change and climate variability, such as temperature and rainfall patterns change monthly.

Aspects studied were hazards of climate change that is the potential decrease in food crops production as a result of decreased productivity, decrease in harvested area, and a decrease in land area. Also, this study included the vulnerability and the level of risk posed by climate change to decrease the production of food crops that has implications for food supply.

3.3 Basis of Data

The data required in this analysis are the data of rainfall and air temperature, cropping patterns, water resources (irrigation), agricultural land use, altitude, population data (demographics), and level of social welfare.

Risk in reduced production due to low productivity, reduction in harvested area, and decreasing agricultural land area is vulnerable to the threat of climate change that requires a quantitative approach to perform prediction. Thus, the results of the analysis are expected to be consideration in the preparation of guidelines for local adaptation.

Types and sources of data that are analyzed in the vulnerability assessment of climate change in agricultural sector are of secondary and primary data. Secondary data came from documents of the Department of Agriculture District, Department of Agriculture of Greater Malang, BPS and other relevant bodies. Primary data are collected through field observation, interviews, and questioners to the key informants consisting of farmers and the heads of farmer groups, agricultural extension, or the competent authorities to handle the affairs of climate and agricultural production at district and level of Greater Malang. Observations were made to systematically record the circumstances of the condition on the pitch and profile production of food crops in 41 Ssub-districts in Greater Malang.

Methods of data analysis in this study are inductive data analysis that is think-flow to draw conclusions from data that are specific to the general conclusions drawn. Inductive method that is used to draw conclusions on the phenomena and elements of climate change and climate variability is illustrated by the data already collected through observation, interviews, and questioners, and then spatially mapped.

In this study, three aspects of climate change impact are analyzed, that are the analysis of hazard events, vulnerability and the risk level. Vulnerability is the degree of ability of an individual or group of people or communities to anticipate and cope with, maintaining the continuity of life and save themselves from the impact caused by the nature hazard. Vulnerability is always changing along with the changes of socio-economic conditions and surrounding environments.

3.3.1 Hazards Data and Their Sources

At most, input data for this hazard analysis of the agriculture sector are obtained from some sources as listed in Table 3.1.

Table 3.1 Crop production hazard data and their sources

No.	Data of Hazard Elements	Duration of data	Sources
1	Productivity of main crops	1993-2010	BPS and DISTAN of Greater Malang
2	Harvested area of main crops	1993-2010	BPS and DISTAN of Greater Malang
3	Production of main crops	1983-2010	BPS and DISTAN of Greater Malang
4	Unharvested area of main crops	2004-2008	BPS and DISTAN of Greater Malang
5	Temperature	1951 – 2008	BMKG and UDEL
6	Rainfall	1951 – 2008	BMKG and UDEL
5	Projection of Temperature	2009 – 2030	SRA1B
6	Projection of Rainfall	2009 – 2030	SRA1B

3.3.2 Vulnerability Data and Their Sources

In this study, the vulnerability uses indicators namely agricultural land area, number of farmers, non irrigation gricultural land area topography (elevation), farmer's income, education level, irrigation infrastructure, access to the capital, population, and landuse. Those data are collected from several sources as listed in Table 3.2.

Table 3.2 Table 3.2 Vulnerability data and their sources

No.	Data	Duration of data	Sources
1	Agricultural land area	2010	*Distan and Bappeda* of Greater Malang
2	Number of farmers	2010	*Distan and Bappeda* of Greater Malang
3	Non irigated agricultural land area	2004-2010	*Distan and Bappeda* of Greater Malang
4	Farmer Income	2010	*Distan and Bappeda* of Greater Malang
5	Level of farmer education	2010	*Distan and Bappeda* of Greater Malang

6	Access to the capital (Bank)	2004-2008	*Bappeda* of Greater Malang
7	Digital Elevation Model (DEM) Shuttle Radar Topography Mission (SRTM) of Greater Malang area	2010	Global Land Cover Facility (Source: http://ftp.glcf.umd.edu/index.html)
8	Administration Boundaries	2010	*Bappeda* of Greater Malang
9	Population	2010 and 2030	BPS (Podes)
11	Land- use	2010 and 2030	*Bappeda* of Greater Malang
12	Irrigation Infrastructure	2004-2010	*Bappeda* of Greater Malang

3.4 Analysis of Hazard

Greater Malang is one of the agriculture areas as a contributor to the national rice stock, but this area is not immune from the threat of catastrophic droughts and floods as a result of erratic rains and extreme weather, thereby potential hazards occur in the form of decreased productivity (crop yield), reduction in harvested area, and a decrease in land area (Figure 3.2).

Cropping pattern and range of time periods of planting rice (growing season) on wetland in Greater Malang are generally lasts from October until February (the planting period I) and from February to June (the planting period II) and in dryland runs from May to September, while corn and soybean planting time is from March to June or May to August. The hazard analysis is focused on the conditions of climatic stimulus parameters during the crop growing period. Hazard analysis uses a primary indicator of decline in commodity production for rice and corn.

In general, crop production is a product of the yield and the harvested area as follows:

$$G = Y . A \text{..} (1)$$

G = crop productions (ton)

Y = crop yield (ton/ha)

A = harvested area (ha)

3.4.1 Crop Yield

(a) The Influence of Air Temperature Rise on Crop Yield

Increased temperature is climatic stimuli to increase respiration rate and shorten crop-life duration. In addition, the increase of air temperature will cause an increase in potential evapotranspiration and reduce the land area receiving irrigation.

The relationship between the temperature rise and increase of crop respiration, which in turn causes a decrease of crop yield, can be written with the following formula, referred as Temperature Quotient. In this case, respiration rate will increase twice for every 10°C temperature increase.

$Q_{10} = 2^{(T-20)/10}$ ....(2)

Furthermore, the decline of crop yield which is caused by the increased respiration due to temperature rise can be approximated by (Handoko *et al.* 1998):

$\Delta Y_{P1} = Y_0(Q_{10}-Q_{10o})$ ....(3)

T = temperature (^oC)

Q_{10o} = *temperature quotient* of initial temperature before temperature rise

Q_{10} = *temperature quotient* of final temperature after temperature rise

ΔY_{p1} = potential of reduced yield as a result of crop respiration (ton/ha)

Y_0 = crop production before temperature rise (ton/ha)

Decrease in crop yield due to shorten crop growing period caused by the temperature rise is approached by the concept of *Thermal Units*, i.e. the rate of plant growth is faster in higher temperatures.

$TU = \Sigma (Ti - Tb)$, $i = 1,2, \ldots , n$ ....(4)

TU = Thermal Unit that is needed by the crop from planting to harvesting

Ti = daily average temperature (^oC) during crop growing period

Tb = base crop temperature (^oC)

n = crop growing period (day)

Then, the crop growing period can be derived as follows:

$n = TU / (T - Tb)$ .... (5)

T is the average air temperature between planting and harvesting (°C).

Thus, the higher the temperature the shorter the crop growing period so the accumulated crop biomass becomes less which results in decreased crop yield. The relationship between the decline in crop yield due to shorter growing period due to increased air temperature, with assumption that yield is linearly proportional to the age of plant, can be written as follows (Handoko et al. 1998):

$\Delta Y_{p2} = Y_o (T_o - T_b)/(T - T_b)$ .... (6)

ΔY_{p2} : potency of decreased yield due to decreased crop growing period (ton/ha)

Y_o : crop yield before air temperature rise (ton.ha)

T_o : initial air temperature (°C)

T : air temperature after temperature rise (°C)

T_b : crop's base temperature (°C)

(b) The Impact of Decreased Rainfall on the Crop Yield

Rainfall determines the crop water availability, especially on rainfed land. By assuming a period of rainfall is spread evenly over the crop growing season, the relationship between rainfall and crop yield can be written as follows:

$Y = k P$ .... (7)

Y = crop yields (ton/ha)

P = rainfall (mm/season)

k = parameter (ton/(ha . mm)

Based on that equation, then the change of rainfall that causes drought or flood will cause decreased crop yield as follows:

$\Delta Y_{p3} = k \,.\, \Delta P$ .... (8)

ΔY_{p3} = potency of crop yield decrease (ton/ha) due to drought

ΔP = the change of rainfall (mm/season)

Then, the impact of temperature and rainfall on the decreased crop yield~~s~~ can be written as:

$\Delta Y_a = \max (\Delta Y_{p1}, \Delta Y_{p2}, \Delta Y_{p3})$ .... (9)

ΔY_a = decrease of crop yield due to temperature rise (ton/ha)

3.4.2 Harvested Area

a) The Impact of Temperature Rise on Harvested Area

Increased air temperatures will cause an increase in crop evapotranspiration, thereby increasing crop water requirements. As a result, irrigated land area that can be filled with sufficient water will be reduced. Potential evapotranspiration that is used as the basis for the calculation of irrigation water can be calculated from air temperature using formula from Thornwaite & Matter, which is a function of temperature (T), as follows:

$ETp = 1.6 \, (10 \,.\, T/I)^a$ .... (10a)

with,

$I = \Delta \, (T/5)^{1.54}$ .... (10b)

$a = 675 \,.\, 10^{-9} \,.\, I^3 - 771 \; 10\text{-}7 \; I^2 + 0.01792 \, I + 0.44239$ .... (10c)

If we can assume that irrigated land area is directly proportional to the value of ETp, while the supply of irrigation water does not change, then the potential reduction in irrigated land area can be predicted as follows:

$\Delta A_{p1} = A_o \, (1 - ETp/ETp_o)$ .... (11)

ΔA_{p1} = potency of decreased irrigated land area (ha) due to increasing ETp

A_o = initial area of irrigated lands (ha)

ETp= evapotranspirasi potential after temperature rise (mm/month)

ETp_o = initial evapotranspirasi potential before temperature rise (mm/month)

b) The Impact of Decreased Rainfall on the Harvested Area

In addition to the effect on the yield, low rainfall resulting in drought and causing crop failure. Conversely, excessive rainfall will cause flooding and crop failure. In this analysis, the decline in harvested area due to drought or flood is derived from the relationship between harvested area and rainfall during the crop growing season, as follows:

$A = c \, . \, P$ .... (12)

Thus, potency of decrease in harvested area can be approximated by:

$\Delta A_{p2} = c \, . \, \Delta P$ .... (13)

ΔA_{p2} : Potency of decrease in harvested area (ha) due to drought or flood

ΔP : The change of rainfall during the growing season (mm)

c : Parameter (ha/mm)

3.4.3 Crop Production

The impact of climate change on rice production from irrigated farm caused by rising temperature and rainfall are calculated based on the decreased yield (Δ Ya) and the harvested areas after the climate has changed (A). Harvested area is calculated from the irrigated land area affected by temperature which increases crop water demand (Δ AP1) and not influenced directly by rainfall (Δ Ap2). Decrease in irrigated lowland rice production due to the increase in temperature and rainfall changes is calculated as follows:

$\Delta G_1 = \Delta Y_{a,1} . A_{o,1} + \Delta A_{p1}.Y_{o,1}$ .... (14)

ΔG_1: Decrease in irrigated-farm paddy productions (ton)

$\Delta Y_{a,1}$: Decrease in irrigated-farm yields (ton/ha)

$A_{o,1}$: Initial irrigated farm area (ha)

ΔA_{p1} : Potency of decrease of harvested area due to the temperature rise (ha)

$Y_{o,1}$: The yield of harvested irrigated farm before temperature rise (ton/ha)

b) The Impact of Climate Change on the Production of Rainfed Paddy

The calculation of decrease in rainfed lowland rice production is the same with irrigated lowland rice, except the harvested area is influenced by rainfall and no irrigation effect. Here is the calculation of reduction in rainfed lowland rice production.

$\Delta G_2 = \Delta Y_{a,2} . A_{o,2} + \Delta A_{p2}.Y_{o,2}$ .... (15)

ΔG_2: Decrease in farm paddy production (ton)

$\Delta Y_{a,2}$: Decrease in rainfed yield (ton/ha)

$A_{o,2}$: Initial rainfed area (ha)

ΔA_{p2} : Potency of decrease in harvested area due to the change of rainfall (ha)

$Y_{o,2}$: The yield of harvested rainfed farm before temperature rise (ton/ha)

c) The Impact of Climate Change on the Crop Production

The impact of climate change on corn production is calculated as in the calculation of the impact on rainfed rice production. However, the parameters used in corn are different.

3.5 Analysis of Vulnerability

Climate change also greatly affects the vulnerability of agricultural sector in Greater Malang. The vulnerability of climate change could be assessed from the three components of vulnerability that are the exposure (E), sensitivity (S), and adaptive capacity (AC). The vulnerability of climate change in Greater Malang strongly depends on the weight of those three components. The greater the exposure and sensitivity will increase the vulnerability of climate change. However, if adaptive capacity is very high then the vulnerability of climate change will be reduced. The weight of exposure, sensitivity, and climate change adaptation capacity in Greater Malang can be studied from each of these indicators.

1. Exposure can be described as a direct danger or "stressor" of climate change that is the hazards caused by the changes of temperature, precipitation, extreme climate events, and sea level in the agricultural sector.
2. Sensitivity describes the human condition and environment which can be vulnerable to hazards, triggering hazards, or reduce the hazards of climate change.
3. Adaptive capacity represents the ability of human or public to adapt to the hazards of climate change.

The extent to which agricultural systems are affected by climate change (exposure), sensitive to climate change, and able to adapt to climate change highly depends on the biophysical and socio-economic conditions and infrastructure of farming communities in Greater Malang.

Vulnerability (V) is proportional to the exposure and sensitivity and inversely proportional with adaptive capacity, which can be expressed by the following equation.

$V = (E , S) / AC$ .... (17)

V = Vulnerability

E = Exposure,

S = Sensitivity,

AC= Adaptation Capacity

Exposure (E) is limited as components of the agricultural sector affected by climate change that is the land area and the number of farmers. The greater the land area and number of farmers in Greater Malang, the value of E will increase. Sensitivity (S) describes the response of the agricultural sector to climate change, stating the magnitude changes in the land area and number of farmers due to climate change. Adaptive Capacity (AC) describes the ability of the agricultural sector for adaptation to climate change. In this study, type of agricultural land, farmers' income, and agricultural land topography are used as an indicator of sensitivity.

Adaptive capacity is the ability of institutions and individuals to avoid hazards potential and take advantage or cope with climate change. In this case, the level of education, income, population, and infrastructure (irrigation system) are an indicator of adaptive capacity. Framework of vulnerability assessment of climate change on agriculture sector is presented in Figure 3.**3**.

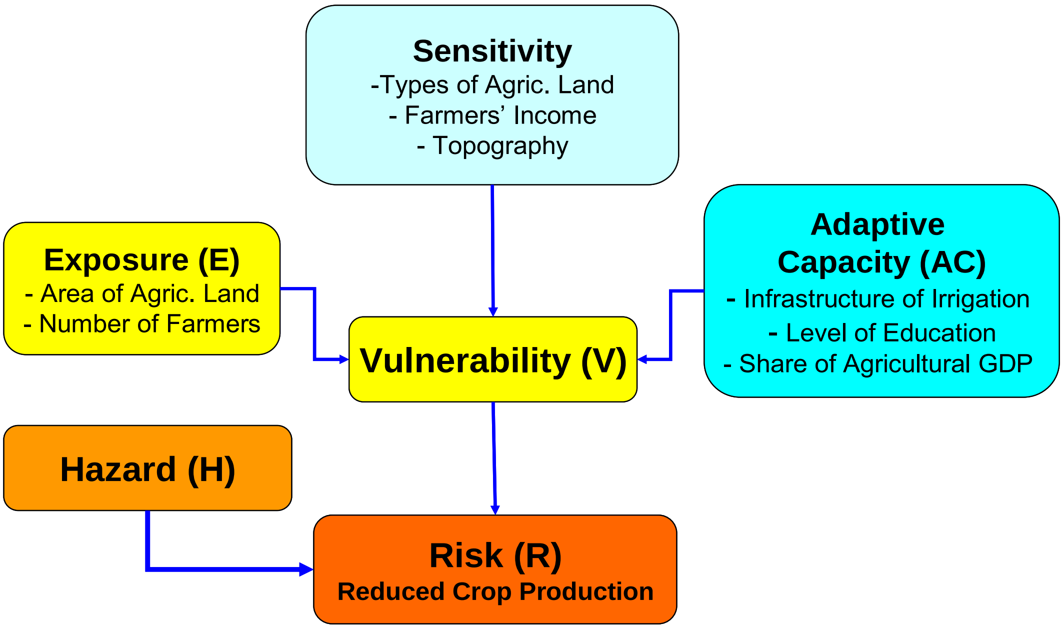


Figure 3.3 Framework of the analysis of hazard potentials, vulnerability, and risk of climate change on agricultural sector

3.6 Analysis of Risk

In the agricultural sector, the concept of risk can be interpreted as a possibility which can lead to losses, represented by the decline in food crop production as a hazard. Furthermore, the hazard may lead to decreased production, directly or indirectly, and the decline of the welfare of farmers and reduction in food supply, that is part of food security in Greater Malang.

The calculation of the risk of climate change in Greater Malang using the following equation:

$$R = H \cdot V \qquad \text{..} \quad (18)$$

R = Risk,

H = Hazard which is calculated on decrease in yield of crop production (Equation 1 to 16),

V = Vulnerability which is calculated by using equation 17

Vulnerability (V) from every region in Greater Malang is mapped spatially to show the most to the least significant vulnerable area for the purpose of adaptation measures. The framework of risk assessment of climate change on agricultural sector is presented in Figure 3.4.

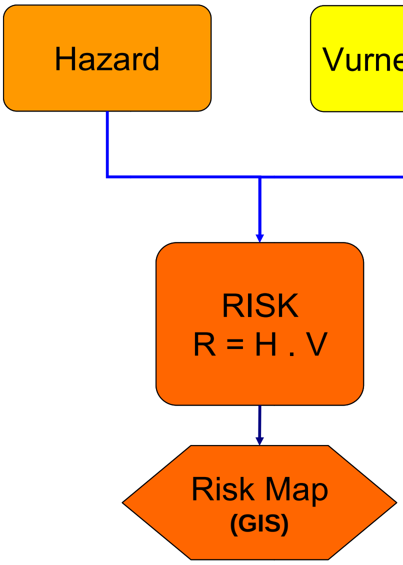


Figure 3.4 Framework of risk analysis of climate change on agricultural sector

3.7 Adaptation Formulation

Adaptation is a real act to adjust the physical environment and social system with a few approaching principles to deal with the potential negative impacts of climate change. The impact of climate change can be perceived on the agricultural sector in Greater Malang. Climate change which is indicated by the shifting of the planting and harvesting season should be anticipated to minimize the impact as hazards and harm risk for vulnerable areas. In this study, there is one effort as response to overcome the problem of climate change that is adaptation. This effort is a response to climate change while the approach can be illustrated in Figure 3.**5**.

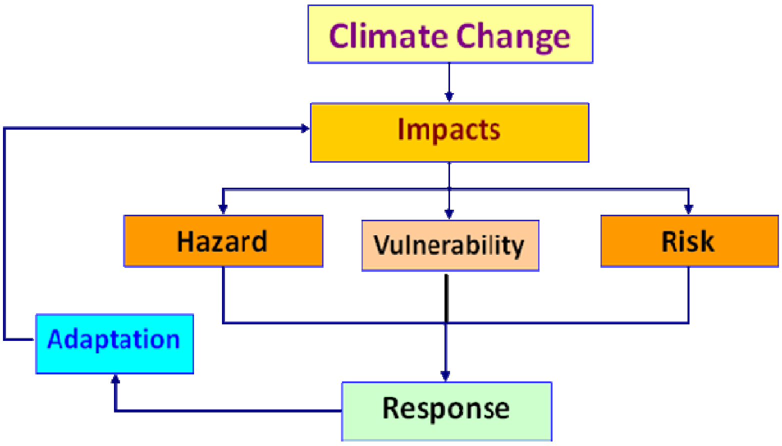


Figure 3.5 Scheme of adaptation approach of climate change on agricultural sector in Greater Malang

Adaptation efforts need to be done to prepare and anticipate the impact that may occur. Efforts to adapt the various impacts of climate change require different strategies, such as adaptation to drought, shift of rainy season, changes of frequency and quantity of rainfall and other extreme events.

Chapter IV Hazard Analysis

4.1 Climate Change in Greater Malang

Based on the analysis of rainfall and air temperature, Greater Malang region has experienced climate change which the air temperature generally increases in the ranged from 0.7 to 0.8 ^{o}C. Meanwhile, rainfall has decreased for majority of Sub-Districts of Greater Malang (0-550 mm) and has increased in Kalipare, Pagak, Bululawang, Sumberpucung, Kromengan, Karangploso, Blimbing, Batu, and Junrejo Sub-Districts (0-166 mm) as shown in Table 4.1. Projection of air temperature in Greater Malang estimates an increase while rainfall projection will relatively remain unchanged (Figure 4.**1**)

Table 4.1 Rainfall and air temperature changes in Greater Malang for 1981-2010 and 2011- 2030 periods

Sub-Dstrict	**Temperature Difference between 1981-2010 and 2011-2030 Periods (^{o}C)**	**Rainfall Difference between 1981-2010 and 2011-2030 Periods (mm)**	**Sub-Dstrict**	**Temperature Difference between 1981-2010 and 2011-2030 Periods (^{o}C)**	**Rainfall Difference between 1981-2010 and 2011-2030 Periods (mm)**
01. Donomulyo	0.7	-335	22. Pakisaji	0.8	-207
02. Kalipare	0.7	13	23. Tajinan	0.8	-39
03. Pagak	0.8	166	24. Tumpang	0.8	-36
04. Bantur	0.7	-25	25. Pakis	0.8	-36
05. Gedangan	0.7	-244	26. Jabung	0.8	-182
06. Sumbermanjing	0.7	-87	27. Lawang	0.8	-232
07. Dampit	0.7	-63	28. Singosari	0.8	-92
08. Tirtoyudo	0.7	-142	29. Karangploso	0.8	62
09. Ampelgading	0.7	-291	30. Dau	0.8	-21
10. Poncokusumo	0.8	-238	31. Pujon	0.8	-384
11. Wajak	0.8	-151	32. Ngantang	0.8	-550
12. Turen	0.7	-94	33. Kasembon	0.8	-543
13. Bululawang	0.8	7	34. Kedungkandang	0.8	-71
14. Gondanglegi	0.7	-22	35. Sukun	0.8	-324
15. Pagelaran	0.7	-29	36. Klojen	0.8	-194
16. Kepanjen	0.8	-57	37. Blimbing	0.8	127
17. Sumberpucung	0.7	32	38. Lowokwaru	0.8	-432
18. Kromengan	0.8	36	39. Batu	0.8	43
19. Ngajum	0.8	-66	40. Junrejo	0.8	165
20. Wonosari	0.8	-53	41. Bumiaji	0.8	-149
21. Wagir	0.8	-158			

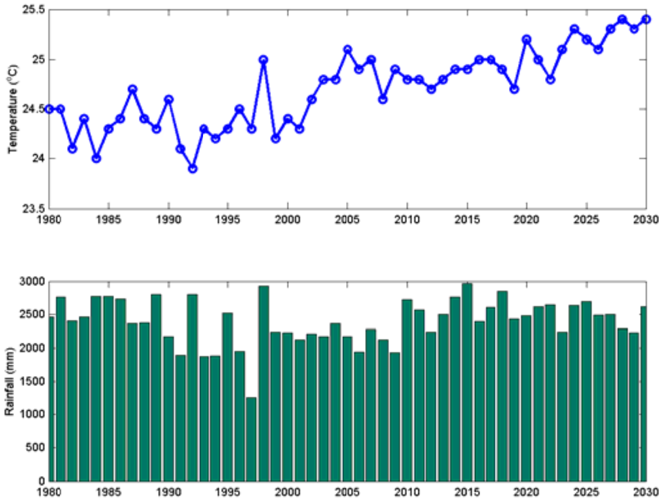


Figure 4.1 Air temperature and rainfall in Greater Malang and their projection until 2030

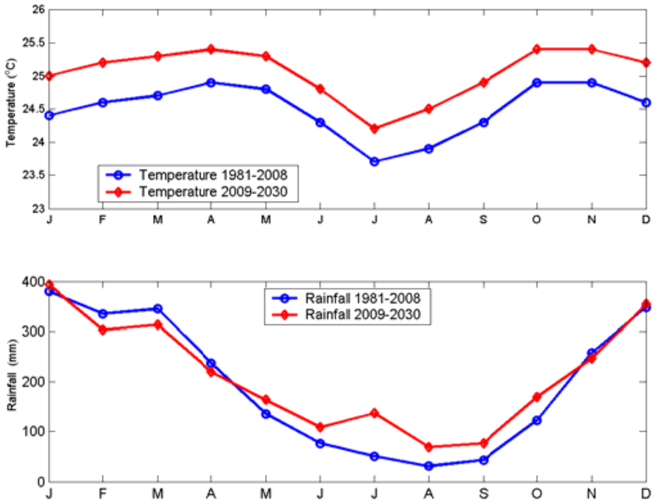


Figure 4.2 The pattern of monthly air temperature and rainfall in Greater Malang

The changes in rainfall and air temperature affect changes of monthly air temperature pattern and hythergraph in Greater Malang region as shown in Figure 4.2 and Figure 4.3. On the hythergraph, it is clearly seen a shift pattern of air temperature to rise (becomes warmer) while the pattern of rainfall does not change significantly.

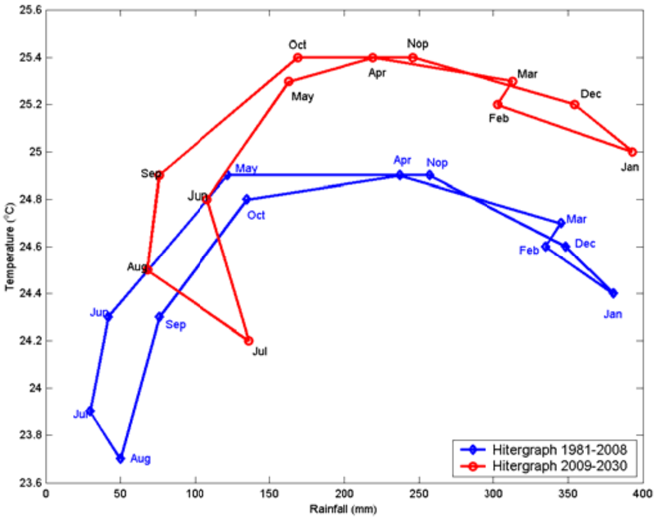


Figure 4.3 Changes in hythergraph in Greater Malang for the period 1981- 2010 (blue) and 2011-2030 period (red).

Based on the analysis of rainfall distribution using Oldeman climate classification, climate types of Greater Malang region has changed as shown in Figures 4.4 and 4.5. Sub-districts of Greater Malang experiencing changes in Oldeman climate types are from C3 to C2 (become wetter), except for Pagak, Bantur, Gedangan, Dampit, Turen, and Pagelaran (C3 to B2) and Sumbermanjing, Tirtoyudo, and Ampelgading (from C2 to B2) as shown in Table 4.2. This will have significant impact on crop water availability, growing season, start of planting, and the preference of crop commodities cultivated in Greater Malang.

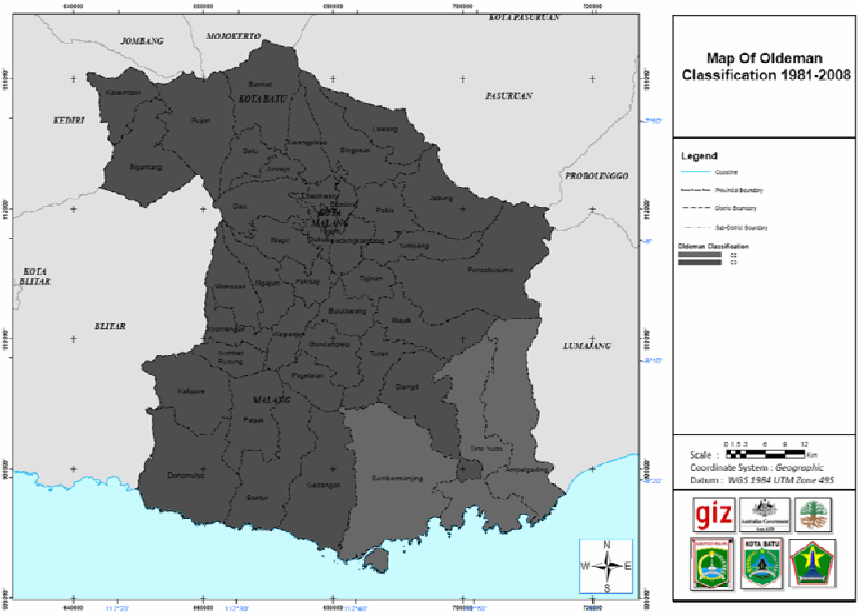


Figure 4.4 Oldeman Classification in Greater Malang for the period of 1981-2010

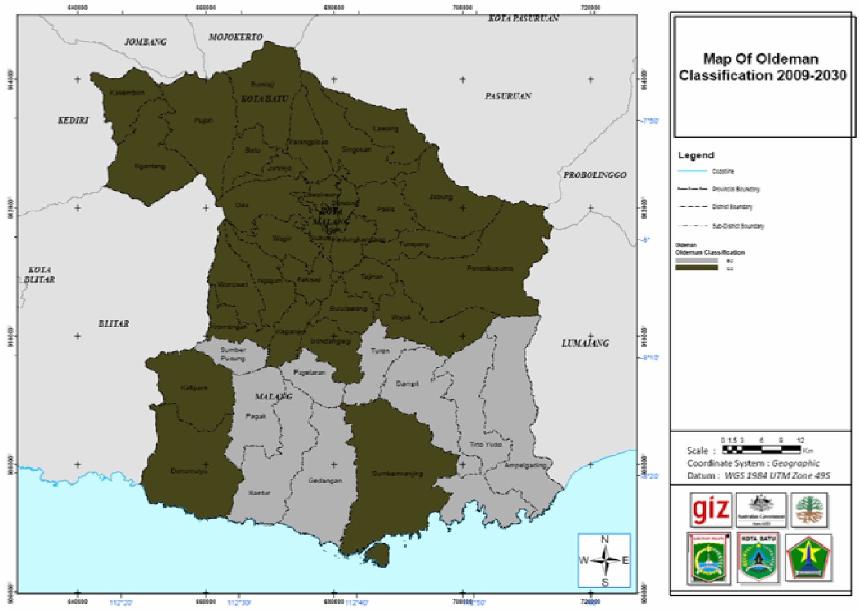


Figure 4.5 Oldeman Classification in Greater Malang for the period of 2011-2030

Table 4.2 Distribution of Climate Type Based on Oldeman Classification in Greater Malang for the periods of 1981-2010 and 2011-2030.

Sub-Dstrict	**Climate Type**		**Sub-Dstrict**	**Climate Type**	
	1981-2010	**2011-2030**		**1981-2010**	**2011-2030**
01. Donomulyo	C3	C2	22. Pakisaji	C3	C2
02. Kalipare	C3	C2	23. Tajinan	C3	C2
03. Pagak	C3	B2	24. Tumpang	C3	C2
04. Bantur	C3	B2	25. Pakis	C3	C2
05. Gedangan	C3	B2	26. Jabung	C3	C2
06. Sumbermanjing	C2	B2	27. Lawang	C3	C2
07. Dampit	C3	B2	28. Singosari	C3	C2
08. Tirtoyudo	C2	B2	29. Karangploso	C3	C2
09. Ampelgading	C2	B2	30. Dau	C3	C2
10. Poncokusumo	C3	C2	31. Pujon	C3	C2
11. Wajak	C3	C2	32. Ngantang	C3	C2
12. Turen	C3	B2	33. Kasembon	C3	C2
13. Bululawang	C3	C2	34. Kedungkandang	C3	C2
14. Gondanglegi	C3	C2	35. Sukun	C3	C2
15. Pagelaran	C3	B2	36. Klojen	C3	C2
16. Kepanjen	C3	C2	37. Blimbing	C3	C2
17. Sumberpucung	C3	C2	38. Lowokwaru	C3	C2
18. Kromengan	C3	C2	39. Batu	C3	C2
19. Ngajum	C3	C2	40. Junrejo	C3	C2
20. Wonosari	C3	C2	41. Bumiaji	C3	C2
21. Wagir	C3	C2			

4.2 Hazard of Climate Change in Agriculture Sector

Climate change is the average change of climate variables (for instance increase in temperature, and change in rainfall), and changes in climate variability. Changes in average climate and climate variability can occur simultaneously. One example of average climate change is the change in average air temperature, and the change of average monthly or annual rainfall in a particular area, such as in Greater Malang. Increasing the earth's surface temperature will have an impact on climate change because rising temperature can increase evaporation resulting more water vapor in the atmosphere. This water vapor will become the source of rain, but not always the case, because the evaporation increase will also cause a certain place to dry faster which then it experiences drought.

The impact of climate change which are often perceived and experienced as hazard and disaster in Greater Malang is a result of changes in climate variability. Examples were the enormous flood in 2010 in Malang District as a result of increase in intensity and frequency of extreme rainfall, planting failures in the early growing season because of low rainfall, harvest failure due to drought and because the rainfall was very heavy at flowering phase of rice (paddy) crop (pollination). Other impacts may also occur are landslide because of the frequency and quantity of heavy rainfall, and forest fires in the prolonged dry season.

Regionally, the most experienced impact is a decline in the quality of natural resources that depend on climate which thus affects the development of other economic sectors. For instance, the average annual rainfall in some sub-district in Greater Malang region has increased, while in some other sub-district it has decreased, and the rainy season or dry season encounter shifting. This poses a problem on increasing water deficit due to reduced water supply. Meanwhile, the rainfed rice fields in Greater Malang are threatened by crop failure and harvest failure. The consequence is production of staple food, especially rice, will be threatened by which food security is going to be disturbed.

Hazard on agricultural sector in Greater Malang is the decline in crop productivity (yield) and a decrease in harvested area, which affect production and cause a risk on food security disturbance. Hazard analysis is carried out by taking the case on staple food crops such as rice and corn which are the eminent crops in Greater Malang. By considering the impact of increasing air temperature, and precipitation changes, on productivity, harvested area, land area, and production of crops such as rice and corn in Greater Malang; the analysis related to hazard is focused on:

(1) Potential decrease in productivity,

(2) Potential reduction in rainfed harvested area,

(3) Potential reduction in irrigated harvested area, and

(4) Potential decline in crop production

This hazard analysis is based on assumption that the decrease in plant productivity and harvested area has a strong relationship with changes in air temperature and rainfall, while sea level rise will cause a reduction in agricultural land area.

Increase in temperature is a climatic stimulus on the increase of crop respiration and shorter crop growing season. In addition, the increase in air temperature will cause an increase in potential evapotranspiration that can reduce the area of irrigated field being supplied with water. Increasing temperature causes higher crop respiration rate which leads to a decrease in crops yield. The decline in crop yield due to shorter crop growing season caused by increasing temperature is approached with the 'Thermal Unit' concept, *i.e.* the crop development rate is faster by the higher air temperature. Thus, the higher air temperature, the shorter crop growing season so the biomass accumulated by the crop becomes less which results in crop yield decline. The relationship between the decline in crop yield due to shorter crop growing season and increasing air temperature assumes that crop yield is linearly related with the growing season (Handoko *et. al.,* 2008).

Rainfall determines the availability of water for the crop, especially on rainfed fields. Assuming a period of rainfall is spread equally during the crop growing season, then there is a strong relationship between rainfall and crop yield. Changes in rainfall causing drought or flood will cause a decrease in crop yield.

Increase in air temperature will lead to higher crop evapotranspiration, thereby crop water requirement will also increase. As a result, the irrigated field area that can be supplied with irrigation water will be smaller. Potential evapotranspiration is used as the basis for the calculation of crop water use to estimate water supply to the crop using irrigated water. Potential evapotranspiration (ETp) can be calculated from air temperature using Thornwaite & Matter formula which is the function of air temperature (T). In this analysis, it is assumed that irrigated field area is proportional to the ETp and the total supply of irrigated water does not change.

Besides its effect on crop yield, low rainfall causes drought which results in harvest failure. Conversely, excessive rainfall will cause flood that also leads to harvest failure. In this analysis, a decline in harvested area due to drought and flood derived from the relationship between harvested areas and rainfall changes.

The impact of climate change on rice production from irrigated rice fields caused by temperature increase is calculated based on the decrease in yield (Δ Y) and harvested area under future climate that has changed from the present condition (A). The harvested area is calculated from the irrigated area affected by temperature that leads to crop water requirement increase (Δ AP1).

Based on the sources of irrigation water, rice fields in Greater Malang consist of (1) technical irrigated rice field, i.e. field that always gets irrigation water throughout the year, (2) semi-technical irrigated rice field, i.e. field which experiences water shortage during the dry season despite having irrigation channel (3) simple irrigated rice field that similar with semi-technical irrigated rice field but has tertiary and quarter irrigation channels which are not permanent, (4) rainfed rice field, the rice irrigation depends entirely on rain.

Greater Malang region is characterized by relatively short rainy season periods with a relatively uneven distribution. The number of rainy days is relatively a few so that the number of wet months is relatively small, and the onset of rainy season is uncertain. The period of rainy season in Greater Malang is generally ranged in October, November, December, January, and February (ONDJF), in which the farmers planting the first rice (rainy season rice). Thereafter, the dry season usually starts in March, so on this month the farmers having a semi-technical irrigated rice field begin to plant seasonal crops or plantation crops, especially tobacco.

Early rainy season in Greater Malang is not constant year-by-year, so the estimate of the beginning of rainy season is important. Usually, the beginning of rainy season at rainfed agricultural areas is indicated by the rainfall in the region which has reached 50 mm or more within 10 days period followed by rainfall over 50 mm in the next 10 days. This phenomenon shows that climate variability affects the agricultural sector. It means that the changes in climate variability have a great chance to cause hazard and risk in the agricultural sector, especially to rice crop in areas which are vulnerable to climate change.

Hazard analysis of decreasing productivity, harvested area, and production is conducted for two main commodity crops (paddy and corn) in Greater Malang. The hazard is divided into five levels; very low, low, moderate, high, and very high. Risk indicators are represented by the green, blue, yellow, orange, and red colours, respectively, as shown in Table 4.4 to Table 4.7. The calssification and weighting factors are shown in Table 4.3.

Table 4.3The hazard level of indicators in decreasing productivity, harvested area, and production of staple food crops up to 2030 in Greater Malang.

No	Level of Hazard	Index of Hazard	Colours
1	Weighting 1, Very Low Hazard	< 0.200	Green
2	Weighting 2, Low Hazard	0.200-0.400	Blue
3	Weighting 3, Moderate Hazard	0.400- 0.600	Yellow
4	Weighting 4, High Hazard	0.600 - 0.800	Orange
5	Weighting 1, Very High Hazard	>0.800	Red

4.2.1 Analysis of Crop Productivity Decrease

The potential decrease in crop productivity is obtained from Equation (9) as shown in Research Methodology (Chapter 3) with the assumption that the increase in temperature is a climatic stimulus to increase respiration rate and shorten crop gowing season which subsequently causes a decline in crop yield. Thus, the higher the temperature the shorter crop gowing season resulting in smaller accumulated crop biomass and less crop yield. The relationship between those variables was used to estimate the decrease in crop yield caused by increasing air temperature (Handoko *et al.* 1998).

Rainfall determines the water availability to support crop growth especially on rainfed fields. If rainfall is spread equally during the crop growing season, rainfall and crop yield are strongly correlatedd. Thus, changes in rainfall causing drought or flood will cause a decrease in crop yield.

Estimated productivity decline on major food crops namely rice and corn in Greater Malang in 2030 is shown in Table 4.4. The projection of productivity and wetland rice field, dryland rice field and corn until 2030 is shown in Figure 4.6.

Table 4.4 Analysis Results of Decrease in Productivity (∆ Ya) of Staple Food Crops in Greater Malang in 2030

Sub-District	**Decreasing Wetland Paddy Productivity**		**Decreasing Dryland Paddy Productivity**		**Decreasing Corn Productivity**	
	(Ton/Ha)	%	(Ton/Ha)	%	(Ton/Ha)	%
01. Donomulyo	-0.715	-12	-0.498	-11	-0.379	-9
02. Kalipare	-0.764	-12	-0.481	-10	-0.395	-9
03. Pagak	-0.728	-12	-0.507	-11	-0.435	-10
04. Bantur	-0.747	-12	-0.587	-13	-0.457	-11

Sub-District	Decreasing Wetland Paddy Productivity		Decreasing Dryland Paddy Productivity		Decreasing Corn Productivity	
	(Ton/Ha)	%	(Ton/Ha)	%	(Ton/Ha)	%
05. Gedangan	-0.747	-12	-0.579	-13	-0.454	-11
06. Sumbermanjing	-0.782	-12	-0.569	-13	-0.460	-11
07. Dampit	-0.792	-12	-0.605	-12	-0.457	-11
08. Tirtoyudo	-0.748	-12	-0.610	-12	-0.468	-11
09. Ampelgading	-0.697	-12			-0.446	-11
10. Poncokusumo	-0.786	-13	-0.548	-13	-0.583	-11
11. Wajak	-0.982	-13	-0.624	-12	-0.530	-11
12. Turen	-0.987	-12	-0.560	-12	-0.599	-10
13. Bululawang	-0.783	-13	-0.551	-12	-0.501	-10
14. Gondanglegi	-1.051	-12			-0.622	-10
15. Pagelaran	-1.054	-12			-0.580	-9
16. Kepanjen	-0.988	-12			-0.544	-10
17. Sumberpucung	-0.915	-12			-0.625	-9
18. Kromengan	-0.743	-12			-0.427	-10
19. Ngajum	-0.810	-13	-0.484	-11	-0.528	-10
20. Wonosari	-0.760	-12	-0.454	-11	-0.475	-10
21. Wagir	-0.792	-13	-0.485	-12	-0.435	-10
22. Pakisaji	-0.821	-13			-0.488	-10
23. Tajinan	-0.753	-13	-0.485	-13	-0.504	-10
24. Tumpang	-0.819	-13			-0.511	-11
25. Pakis	-1.038	-13			-0.634	-10
26. Jabung	-0.838	-14	-0.529	-13	-0.543	-11
27. Lawang	-1.053	-14			-0.503	-11
28. Singosari	-1.147	-14	-0.718	-11	-0.559	-11
29. Karangploso	-0.852	-13	-0.568	-12	-0.478	-11
30. Dau	-0.803	-13	-0.482	-12	-0.492	-10
31. Pujon	-0.726	-13			-0.527	-10
32. Ngantang	-0.770	-13			-0.509	-10
33. Kasembon	-0.761	-13	-0.464	-11	-0.485	-10
34. Kedungkandang	-0.880	-13			-0.392	-11
35. Sukun	-1.001	-13			-0.384	-11
36. Klojen	0.000	0				-3
37. Blimbing	-0.934	-13				-3
38. Lowokwaru	-0.901	-13			-0.392	-11
39. Batu	-0.839	-13			-0.420	-11
40. Junrejo	-0.844	-13			-0.423	-11
41. Bumiaji	-0.869	-13			-0.440	-11

As the impact of climate change, the productivity of agricultural crops will experience decrease, 12.4%, 10.4%, and 10.0% for wetland paddy, dryland paddy and corn in 2030, respectively. Annually, the average decreases of productivities are 0.62%, 0.52%, and 0.50% for wetland paddy, dryland paddy, and corn, respectively.

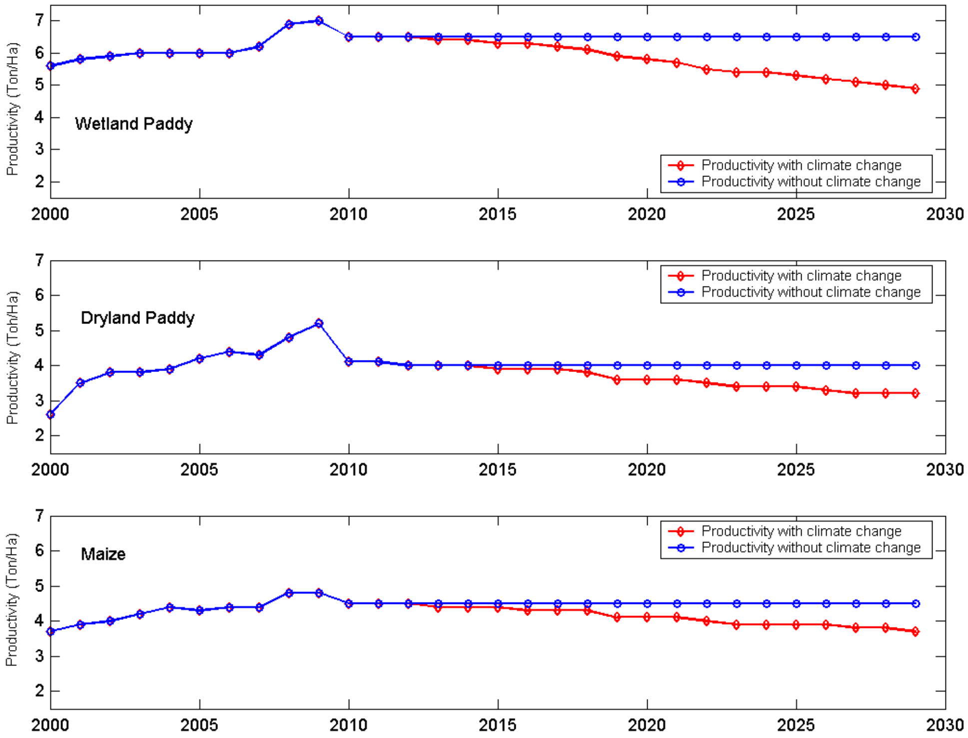


Figure 4.6Projections of productivity of wetland paddy, dryland paddy, and corn (maize) in Greater Malang up to 2030.

Based on the potential analysis results, decrease in productivity of food crops in Greater Malang region indicates that the accumulated decrease of wetland paddy productivity will be 0.829 ton/ha in 2030. Majority of Greater Malang irrigated paddy areas will generally experience potential productivity decrease up to 0.982 ton/ha (very high hazard level) except for Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, Singosari, sukun, and Blimbing Sub-Districts.

The accumulated productivity decrease of dryland paddy for Greater Malang in 2030 has an average of 0.542 ton/ha and productivity decrease of dryland paddy will be up to 0.587 ton/ha (very high hazard level), except for Bantur, Gedangan, Dampit, Tirtoyudo, Wajak, and Singosari Sub-Districts.

Meanwhile, the accumulated productivity decrease of corn has an average of 0.471 ton/ha in 2030 with corn productivity decrease is up to 0.509 ton/ha (very high hazard level) except for Poncokusumo, Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Tumpang, Pakis, Jabung, Singosari, Pujon, and Ngantang Sub-Districts.

4.2.2 Analysis of Harvested Area Decrease in Rainfed Fields

Decrease in harvested area is obtained from equation (11) as shown in the Research Methodology (Chapter 3) considering that the decrease in harvested area of food crops is related with changes in air temperature and rainfall.

Besides its effect on crop productivity, low rainfall causes drought which results in harvest failure. Conversely, excessive rainfall will cause flood that also leads to harvest failure. In this analysis, a decline in harvested area due to drought and flood was derived from the relationship between harvested areas with rainfall changes.

The analysis results on decreasing harvested area of staple food crops namely paddy and corn in Greater Malang in 2030 are shown in Table 4.5.

Table 4.5 Analysis Results of Decrease in Harvested Area of Staple Crops on Rainfed Fields in Greater Malang in 2030

Sub-District	Type of Crops		
	Rainfed Paddy (Ha)	Dryland Paddy (Ha)	Corn (Ha)
01. Donomulyo	-944	-232	-947
02. Kalipare	-972	-600	-2860
03. Pagak	-114	-356	-575
04. Bantur	-689	-248	-1395
05. Gedangan	-363	-62	-1430
06. Sumbermanjing	-354	-8	-904
07. Dampit	-1437	-814	-2868
08. Tirtoyudo	-292	-218	-732
09. Ampelgading	-173	0	-169
10. Poncokusumo	-238	0	-1318
11. Wajak	-202	-90	-5065
12. Turen	-218	-11	-1007
13. Bululawang	0	-2	-103
14. Gondanglegi	-49	0	-111
15. Pagelaran	-92	0	-245
16. Kepanjen	-6	0	-27
17. Sumberpucung	0	0	-701
18. Kromengan	0	0	-73
19. Ngajum	-524	-47	-249
20. Wonosari	-407	-2	-219
21. Wagir	-95	-34	-827
22. Pakisaji	0	0	-21
23. Tajinan	-397	-1	-1112
24. Tumpang	-91	0	-1091
25. Pakis	-55	0	-222
26. Jabung	-49	-63	-728
27. Lawang	-271	0	-530
28. Singosari	-214	-148	-354
29. Karangploso	-174	-17	-345
30. Dau	-44	-10	-559
31. Pujon	-42	0	-867
32. Ngantang	-301	0	-813
33. Kasembon	-454	-7	-819
34. Kedungkandang	0	0	-151
35. Sukun	0	0	-10
36. Klojen	0	0	0
37. Blimbing	0	0	0
38. Lowokwaru	0	0	-14
39. Batu	-2	0	-384
40. Junrejo	-3	0	-234
41. Bumiaji	-3	0	-620

The potential reduction of harvested area in Greater Malang in 2030 for rainfed paddy is about 9,269 ha and for dryland paddy field is approximately 2970 ha. The reduction accumulation for corn field is about 30,699 ha.

In general, climate change in Greater Malang in 2030 is not potentially strong on the hazard of harvested area reduction of rainfed paddy, dryland paddy, and corn. Although the air temperature increases, but the rainfall in that region experiences slight decline, so the occurrence of harvest failure is relatively small. However, Donomulyo, Kalipare, Dampit, and Wajak Sub-Districts need to be on alert because of the potential decrease in harvested area.

4.2.3 Analysis of Harvested Area Decrease in Irrigated Fields

The decrease in harvested area in irrigated fields is obtained from equation (11) as shown in the Research Methodology (Chapter 3). Air temperature rise will lead to increase in crop evapotranspiration, thereby crop’s water requirement will also increase. As a result, the irrigated land area that can be supplied with water will be reduced. The potential evapotranspiration (ETp) is used as the basis for the calculation of water irrigation from the air temperature using the Thornwaite & Matter formula which is a function of temperature (T). In this analysis, it is assumed that irrigated land area is linearly proportional to the ETp and the supply of irrigation water does not change. The analysis results of harvested area decrease of irrigated paddy in Greater Malang in 2030 are shown in Table 4.6.

Table 4.6 Analysis Results of decrease in harvested area of irrigated paddy in Greater Malang in 2030

Sub-Dstrict	Irrigated Paddy (Ha)	**Sub-Dstrict**	Irrigated Paddy (Ha)
01. Donomulyo	-178	22. Pakisaji	-171
02. Kalipare	0	23. Tajinan	-137
03. Pagak	0	24. Tumpang	-122
04. Bantur	-124	25. Pakis	-178
05. Gedangan	0	26. Jabung	-185
06. Sumbermanjing	-67	27. Lawang	-135
07. Dampit	-300	28. Singosari	-257
08. Tirtoyudo	-63	29. Karangploso	-219
09. Ampelgading	-42	30. Dau	-21
10. Poncokusumo	-104	31. Pujon	-14
11. Wajak	-75	32. Ngantang	-113
12. Turen	-230	33. Kasembon	-129
13. Bululawang	-99	34. Kedungkandang	-49
14. Gondanglegi	-86	35. Sukun	-55
15. Pagelaran	-163	36. Klojen	0
16. Kepanjen	-277	37. Blimbing	-18
17. Sumberpucung	-181	38. Lowokwaru	-54
18. Kromengan	-206	39. Batu	-28
19. Ngajum	-149	40. Junrejo	-39
20. Wonosari	-52	41. Bumiaji	-55
21. Wagir	-72		

The accumulated potential of harvested area decrease of irirgated Paddy fields in Greater Malang region is about 4,447 ha in 2030 (average of 222 ha per year). In general, the decrease of irrigated paddy field is less than 181 ha (high hazard level), except for Dampit, Kepanjen, Singosari, Turen, Sumberpucung, Kromengan, Jabung, and Karangploso Sub-Districts. Therefore, the decrease due to climate change is not as alarming as the decline in land area due to land conversion (0.77% or 284 ha per year).

4.2.4 Analysis of Decrease in Crop Production

Crop production (paddy and corn) is a result of harvest (Y) multiplied by harvested area (A), so the hazard of decreasing production is derived from those two variables that have been analyzed previously. The results of hazard analysis in the decrease in production of staple food such as paddy, and corn in Greater Malang in 2030 is conducted using the SRA1B scenario which is shown in Table 4.11 and Figure 4.7 and Figure 4.8. Based on the analysis, the decrease in production changes dynamically from year to year until 2030. The projection analysis of decreasing production as the result of climate change is then compared with the condition in 2010. The projection results of production of wetland paddy, dryland paddy, and corn until 2030 are shown in Figure 4.9.

Table 4.7 Analysis Results of Decreasing Staple Crops Production in Greater Malang in 2030

Sub-District	Decreasing Wetland Paddy Production		Decreasing Dryland Paddy Production		Decreasing Corn Production	
	(Ton)	%	(Ton)	%	(Ton)	%
01. Donomulyo	-1691	-11	-309	-14	-731	-9
02. Kalipare	-1381	-11	-652	-12	-2261	-9
03. Pagak	-187	-13	-434	-13	-515	-10
04. Bantur	-1247	-12	-387	-17	-1294	-11
05. Gedangan	-553	-12	-164	-28	-1317	-11
06. Sumbermanjing	-722	-12	-44	-50	-852	-11
07. Dampit	-3080	-12	-1091	-14	-2633	-11
08. Tirtoyudo	-658	-12	-350	-16	-707	-11
09. Ampelgading	-419	-12	0	0	-173	-12
10. Poncokusumo	-940	-12	-7	-51	-1539	-11
11. Wajak	-912	-12	-203	-21	-5327	-10
12. Turen	-2858	-12	-62	-50	-1216	-10
13. Bululawang	-939	-12	-19	-51	-124	-12
14. Gondanglegi	-1147	-12	0	0	0	0
15. Pagelaran	-2210	-11	0	0	-307	-10
16. Kepanjen	-3351	-11	0	0	-53	-17
17. Sumberpucung	-2083	-11	0	0	0	0
18. Kromengan	-1886	-11	0	0	-79	-12
19. Ngajum	-1424	-11	-105	-25	-280	-10
20. Wonosari	-646	-12	-18	-50	-224	-10
21. Wagir	-664	-12	-76	-25	-730	-10
22. Pakisaji	-1633	-11	0	0	-40	-19
23. Tajinan	-1195	-12	-12	-50	-1129	-10
24. Tumpang	-1109	-12	0	0	-1123	-11
25. Pakis	-2000	-12	0	0	-301	-11
26. Jabung	-1651	-13	-115	-22	-800	-11
27. Lawang	-1445	-13	0	0	-544	-12
28. Singosari	-3035	-12	-292	-16	-409	-11
29. Karangploso	-1957	-12	-83	-44	-343	-11
30. Dau	-211	-13	-50	-50	-561	-10
31. Pujon	-130	-13	0	0	-921	-10
32. Ngantang	-985	-11	0	0	-836	-10
33. Kasembon	-1083	-11	-37	-50	-804	-10
34. Kedungkandang	-504	-12	0	0	-132	-12
35. Sukun	-632	-12	0	0	-22	-29
36. Klojen	0	0	0	0	0	0

Sub-District	Decreasing Wetland Paddy Production		Decreasing Dryland Paddy Production		Decreasing Corn Production	
	(Ton)	%	(Ton)	%	(Ton)	%
37. Blimbing	-205	-14	0	0	0	0
38. Lowokwaru	-543	-12	0	0	-25	-24
39. Batu	-276	-12	0	0	-336	-11
40. Junrejo	-374	-12	0	0	-211	-11
41. Bumiaji	-510	-12	0	0	-558	-11

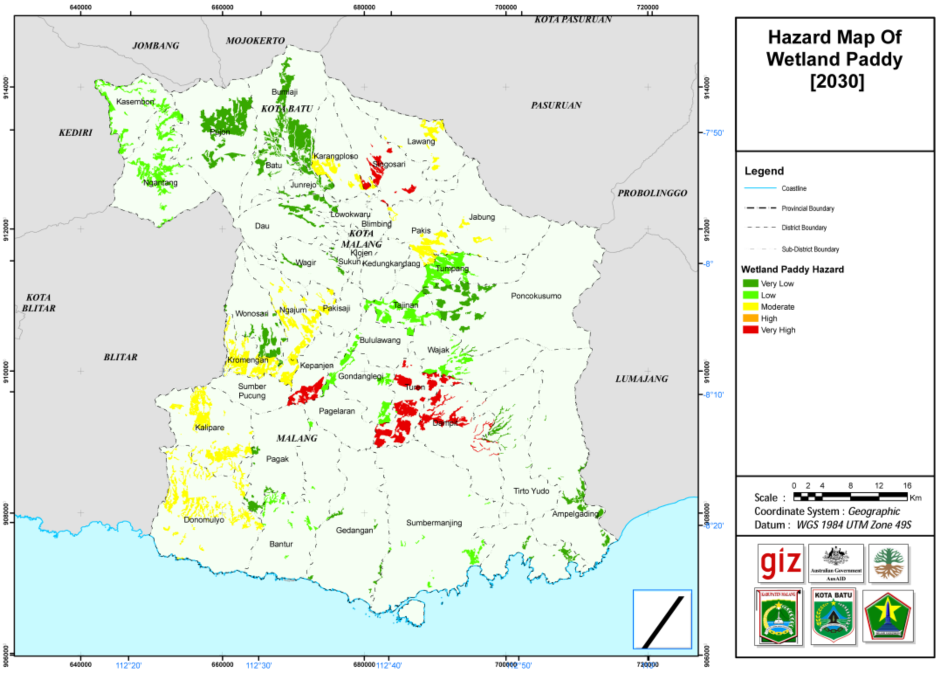


Figure 4.7 Map of 2030 Wetland Paddy Hazard

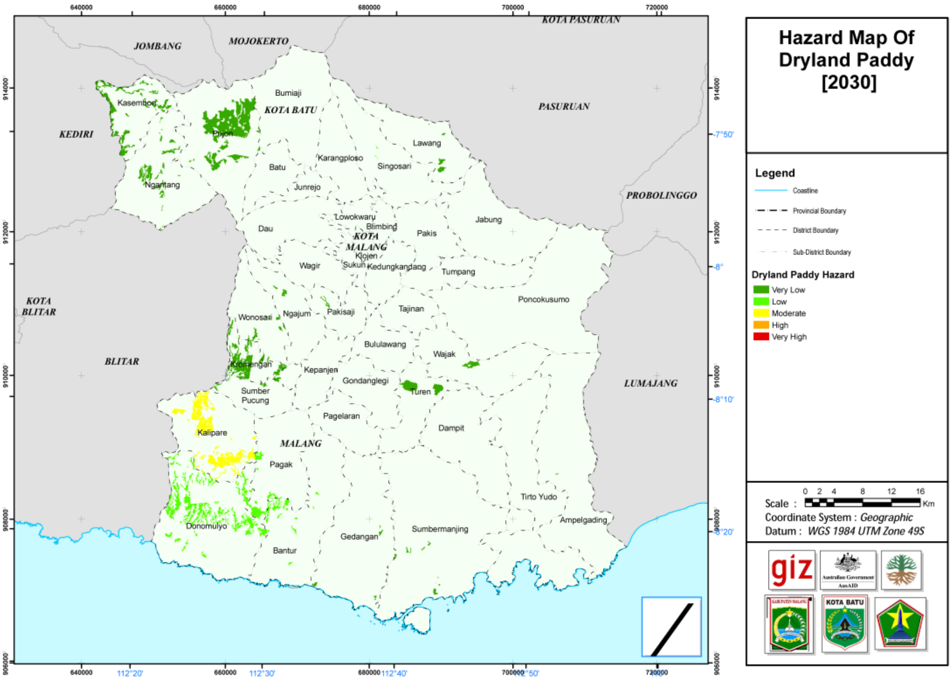


Figure 4.8 Map of 2030 Dryland Paddy Hazard

Due to the impact of climate change, agricultural crops experience accumulated production decrease of 11.9%, 31.8%, and 11.6% for wetland paddy, dryland paddy, dan corn in 2030, respectively. The average production decreases 0.59%, 1.59%, and 0.58% per year for wetland paddy, dryland paddy, and corn, respectively.

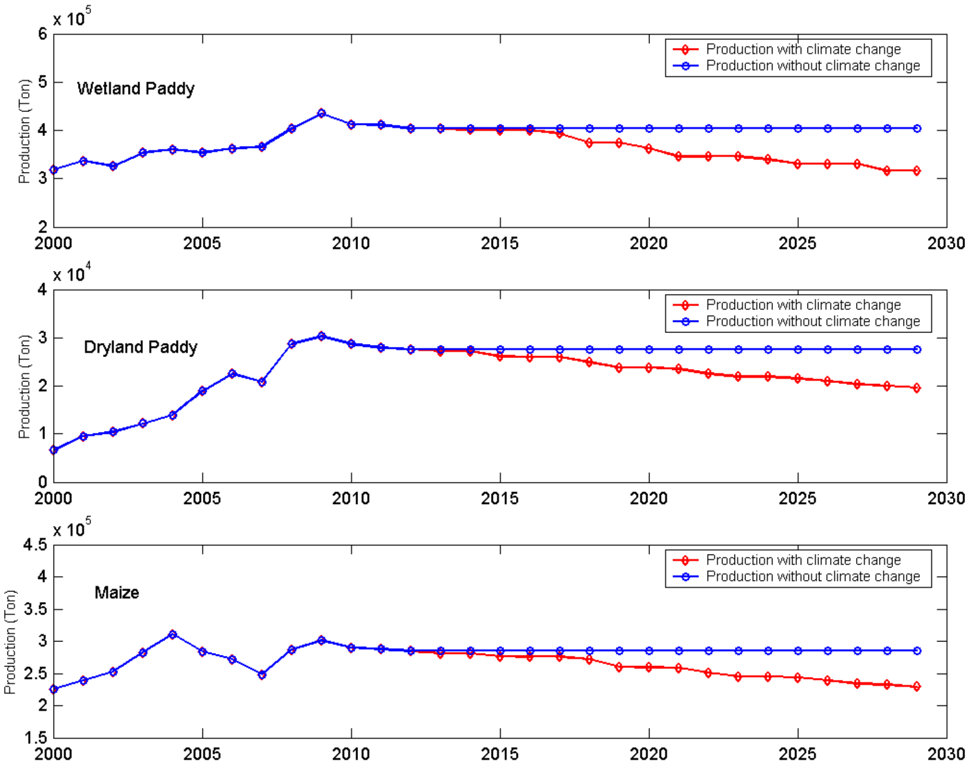


Figure 4.9 Productivity projections of production of wetland paddy, dryland paddy, and corn (maize) in Greater Malang up to 2030

The hazard potential of decrease in wetland paddy production in Greater Malang area is about 4,8476 tons of dry milled grain (DMG) (accumulation from 2012 to 2030). By 2030, most parts of Greater Malang experience this hazard potential of decrease in wetland paddy production up to 2,083 tons of dry milled grain (DMG) (high hazard level), except in Dampit, Turen, Kepanjen, Singosari, Pagelaran, and Sumberpucung Sub-Districts. Meanwhile, the hazard potential of decrease in dryland paddy production is about 4,510 tons of DMG in 2030. By 2030, almost the entire parts of Greater Malang region will experience the hazard potential of decreasing dryland paddy production up to 1,091 tons of DMG, except for Dampit Sub-District. The hazard potential of decrease in corn production in Greater Malang in 2030 are 29457 tons, almost the entire parts of Greater Malang region will experience the hazard potential of decreasing corn production up to 5,327 tons, except for Wajak Sub-District.

Generally, climate change in Greater Malang in 2030 will lead to decreasingproduction of paddy and corn. This is due to the potential decrease in productivity and harvested area of paddy and corn which is the consequences of air temperature increase and rainfall decrease. Areas that have high potential for decreasing crop production in Greater Malang are Dampit, Turen, Kepanjen, and Singosari Sub-Districts for wetland paddy; Dampit Sub-Districts for dryland paddy and Wajak Sub-District for corn. The summary of climate change analysis results on agriculture sector in Greater Malang according to the baseline condition and SRA1B scenario projection in 2030 are shown in Table 4.8 to Table 4.11.

Table 4.8 Distribution of regions that experience decreasing productivity rate on staple food crops in Greater Malang in 2030.

Type of Crops	Sub-District		
	Moderate Hazard	High Hazard	Very High Hazard
Wetland Paddy	-	Donomulyo, Kalipare, Pagak, Bantur, Gedongan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Bululawang, Poncokusumo, Sumberpucung, Kromengan, Ngajum, Wonosari, Wagir, Pakisaji, Tajinan, Tumpang, Jabung, Karangploso, Dau, Pujon, Ngantang, Kasembon, Kedungkandang, Lowokwaru, Batu, Bumiaji, and Junrejo	Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, Singosari, sukun, and Blimbing
Dryland Paddy	-	Donomulyo, Kalipare, Pagak, Sumbermanjing, Bululawang, Poncokusumo, Ngajum, Wonosari, Wagir, Tajinan, Turen, Jabung, Karangploso, and Kasembon	Bantur, Gedangan, Dampit, Tirtoyudo, Wajak, and Singosari
Corn	Donomulyo	Kalipare, Pagak, Bantur, Gedongan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Bululawang, Kromengan, Ngajum, Wonosari, Wagir, Pakisaji, Tajinan, Sukun, Lawang, Karangploso, Dau, Kasembon, Kedungkandang, Lowokwaru, Batu, Junrejo, and Bumiaji	Poncokusumo, Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Tumpang, Pakis, Jabung, Singosari, Pujon, and Ngantang

Table 4. 9 Distribution of regions that experience decreasing harvested area on staple food crops in Greater Malang in 2030.

Type of	Sub-District

Crops	Moderate Hazard	High Hazard	Very High Hazard
Rainfed Paddy	Bantur and Kalipare	Donomulyo and Kalipare	Dampit
Drayland Paddy	-	Kalipare	Dampit
Corn	Dampit	-	Wajak

Table 4.10 Distribution of regions that experience decreasing irrigation paddy harvested area in Greater Malang in 2030.

Type of Crop	Sub-District		
	Moderate Hazard	High Hazard	Very High Hazard
Irrigated Paddy	Donomulyo, Bantur, Pagelaran, Ngajum, Pakisaji, Tajinan, Tumpang, Pakis, Lawang, and Kasemobon	Turen, Sumberpucung, Kromengan, Jabung, and Karangploso	Dampit, Kepanjen, and Singosari

Table 4.11 Distribution of regions that experience decreasing yield of staple food crops in Greater Malang in 2030.

Type Crops	Sub-District		
	Moderate Hazard	High Hazard	Very High Hazard
Wetland Paddy	Donomulyo, Kalipare, Kromengan, Ngajum, Pakisaji, Pakis, Jabung, Lawang, and Karangploso	Pagelaran and Sumberpucung	Dampit, Turen, Kepanjen, and Singosari
Drayland Paddy	Kalipare	-	Dampit
Corn	Kalipare and Dampit	-	Wajak

Potential reduction in productivity and harvested area greatly cause decreasing food crop production of Greater Malang. If the hazard becomes a reality, there will be a decrease in food supply, specially paddy and corn. Therefore, food security and food balance in Greater Malang, as well as Greater Malang's contribution to the East Java province provision of paddy stock, will be disturbed.

Chapter V CLIMATE CHANGE VULNERABILITY ASSESSMENT ON AGRICULTURE SECTOR

5.1. Vulnerability Assessment on Agriculture Sector

Climate change vulnerability on agriculture sector in Greater Malang is assessed from three vulnerability components; they are exposure (E), sensitivity (S), and adaptive capacity (AC). The weight of each component can be studied from its indicator.

1. Exposure can be represented as a direct hazard or stressor of climate change consisting of temperature change, precipitation, extreme climate events, and sea level rise.
2. Sensitivity represents the condition of people and its environment which can be vulnerable to hazards, triggering hazards, or reducing hazards of climate change.
3. Vulnerability represents people's ability to adapt to climate change.

Climate change vulnerability on agriculture sector in Greater Malang is affected by exposure, sensitivity, and adaptive capacity indicators.
Vulnerability (V) assessment uses an assumption that vulnerability is directly proportional with exposure and sensitivy while inversely proportional with adaptive capacity, which can be expressed as

$$V = (E \,.\, S) / AC$$

V = Vulnerability
E = Exposure
S = Sensitivity
AC= Adaptive Capacity

The indicators for the three vulnerability components are:

1. Agricultural land area and number of farmers as exposure's indicators.

2. Agricultural land types (non-irrigated), topography (elevation), and farmers' income as sensitivity's indicators.
3. Irrigation infrastructures, level of education, and access to the capital as adaptive capacity's indicators.

Greater Malang has a tropical climate with two seasons, wet and dry seasons. The duration of wet season is relatively short compared to the dry season and the onset of wet season is often uncertain, affects agriculture sector especially the planting time and growing period. Landuse, agricltural land area, topography (elevation), irrigation infrastructure, and access to the capital for every sub-district in Greater Malang are relatively varying. Those factors are considered in the vulnerability assessment of agriculture sector in Greater Malang to assess the vulnerability level (vulnerable, moderately vulnerable, or very vulnerable) to climate change for every district in Greater Malang. Every factor is weighted using the "*pairwise comparison*" which is then mapped spatially by using the *Geographic Information System* (GIS). From the analysis result, we can see the distribution of spatial vulnerability for every sub-district in Greater Malang.

5.2. Vulnerability on Agriculture Sector

The result of vulnerability analysis using 2010 data (baseline) indicates that each sub-district shows different level of spatial vulnerability. The 2030 vulnerability is analyzed based on the projection of vulnerability indicators.

5.2.1 Exposure (E)

The exposure to climate change on agriculture sector in Greater Malang uses two indicators; agriculture land area and number of farmers. The results of exposure analysis are shown in Table 5.1 and Table 5.2.

Table 5.1Climate change exposure to agriculture sector in Greater Malang (2010)

Sub-Districts	Indicators		Total E	Index of E	Level of Exposure
	AAL	NF			
01. Donomulyo	1.0000	0.4896	0.265	1.000	Very High
02. Kalipare	0.5431	0.4456	0.159	0.601	High

Sub-Districts	Indicators		Total E	Index of E	Level of Exposure
	AAL	NF			
03. Pagak	0.5377	0.3326	0.149	0.560	Moderate
04. Bantur	0.9076	0.4721	0.243	0.917	Very High
05. Gedangan	0.6803	0.3652	0.183	0.691	High
06. Sumbermanjing	0.8474	0.6413	0.244	0.921	Very High
07. Dampit	0.3493	0.7733	0.144	0.545	Moderate
08. Tirtoyudo	0.3883	0.4149	0.122	0.461	Moderate
09. Ampelgading	0.5213	0.3774	0.149	0.561	Moderate
10. Poncokusumo	0.7777	0.6094	0.226	0.852	Very High
11. Wajak	0.5025	0.5324	0.158	0.595	Moderate
12. Turen	0.4097	0.7386	0.155	0.584	Moderate
13. Bululawang	0.3661	0.4063	0.117	0.440	Moderate
14. Gondanglegi	0.4650	0.5123	0.148	0.557	Moderate
15. Pagelaran	0.3077	0.4315	0.106	0.399	Low
16. Kepanjen	0.3291	0.6122	0.126	0.475	Moderate
17. Sumberpucung	0.2103	0.3593	0.078	0.293	Low
18. Kromengan	0.2750	0.2603	0.084	0.316	Low
19. Ngajum	0.4153	0.3304	0.121	0.457	Moderate
20. Wonosari	0.1616	0.2939	0.061	0.231	Low
21. Wagir	0.4303	0.5017	0.139	0.525	Moderate
22. Pakisaji	0.2563	0.4908	0.099	0.375	Low
23. Tajinan	0.2990	0.3266	0.095	0.357	Low
24. Tumpang	0.4119	0.4903	0.134	0.506	Moderate
25. Pakis	0.3706	0.8023	0.152	0.572	Moderate
26. Jabung	0.4558	0.4566	0.141	0.532	Moderate
27. Lawang	0.3701	0.5963	0.134	0.505	Moderate
28. Singosari	0.4281	1.0000	0.181	0.684	High
29. Karangploso	0.3230	0.3574	0.103	0.388	Low
30. Dau	0.2680	0.3758	0.092	0.347	Low
31. Pujon	0.3232	0.4002	0.107	0.402	Moderate
32. Ngantang	0.3469	0.3827	0.110	0.416	Moderate
33. Kasembon	0.2455	0.2037	0.072	0.273	Low
34. Kedungkandang	0.1698	0.2036	0.055	0.209	Low
35. Sukun	0.0703	0.2196	0.035	0.130	Very Low
36. Klojen	0.0000	0.1592	0.014	0.052	Very Low
37. Blimbing	0.0144	0.2148	0.022	0.082	Very Low
38. Lowokwaru	0.0386	0.2284	0.028	0.107	Very Low
39. Batu	0.1343	0.4141	0.066	0.247	Low
40. Junrejo	0.1260	0.1724	0.043	0.162	Very Low
41. Bumiaji	0.2313	0.7529	0.116	0.439	Moderate

Note : AAL : Area of Agriculture Land (expressed as indices range 0-1)
NF : Number of Farmers (expressed as indices range 0-1)
E : Exposure (expressed as indices range 0-1)

Table 5.2Projection of climate change exposure (E) on agriculture sector in Greater Malang (2030)

Sub-District	Indicators		Total E	Index of E	Level of Exposure
	AAL	NF			
01. Donomulyo	1.0000	0.5606	0.265	1.000	Very High
02. Kalipare	0.5431	0.4658	0.159	0.594	Moderate
03. Pagak	0.5377	0.3470	0.149	0.552	Moderate
04. Bantur	0.9076	0.4933	0.243	0.903	Very High
05. Gedangan	0.6803	0.3525	0.183	0.671	High
06. Sumbermanjing	0.8474	0.6551	0.244	0.905	Very High
07. Dampit	0.3493	0.8123	0.144	0.545	Moderate
08. Tirtoyudo	0.3883	0.4376	0.122	0.458	Moderate
09. Ampelgading	0.5213	0.3923	0.149	0.553	Moderate
10. Poncokusumo	0.7777	0.5880	0.226	0.826	Very High
11. Wajak	0.5025	0.5791	0.158	0.597	Moderate
12. Turen	0.4097	0.7517	0.155	0.575	Moderate
13. Bululawang	0.3661	0.4214	0.117	0.435	Moderate
14. Gondanglegi	0.4650	0.3674	0.148	0.499	Moderate
15. Pagelaran	0.3077	0.4540	0.106	0.397	Low
16. Kepanjen	0.3291	0.8380	0.126	0.536	Moderate
17. Sumberpucung	0.2103	0.1835	0.078	0.231	Low
18. Kromengan	0.2750	0.2717	0.084	0.312	Low
19. Ngajum	0.4153	0.3396	0.121	0.449	Moderate
20. Wonosari	0.1616	0.3207	0.061	0.235	Low
21. Wagir	0.4303	0.5007	0.139	0.513	Moderate
22. Pakisaji	0.2563	0.5103	0.099	0.373	Low
23. Tajinan	0.2990	0.3321	0.095	0.351	Low
24. Tumpang	0.4119	0.5093	0.134	0.500	Moderate
25. Pakis	0.3706	0.7796	0.152	0.552	Moderate
26. Jabung	0.4558	0.4707	0.141	0.524	Moderate
27. Lawang	0.3701	0.6346	0.134	0.506	Moderate
28. Singosari	0.4281	1.0000	0.181	0.669	High
29. Karangploso	0.3230	0.3829	0.103	0.387	Low
30. Dau	0.2680	0.3991	0.092	0.347	Low
31. Pujon	0.3232	0.4266	0.107	0.401	Moderate
32. Ngantang	0.3469	0.3879	0.110	0.408	Moderate
33. Kasembon	0.2455	0.2070	0.072	0.267	Low
34. Kedungkandang	0.1698	0.1952	0.055	0.201	Low
35. Sukun	0.0703	0.1777	0.035	0.114	Very Low
36. Klojen	0.0000	0.1102	0.014	0.035	Very Low
37. Blimbing	0.0144	0.1740	0.022	0.067	Very Low
38. Lowokwaru	0.0386	0.2033	0.028	0.096	Very Low
39. Batu	0.1343	0.3548	0.066	0.223	Low
40. Junrejo	0.1260	0.1472	0.043	0.150	Very Low
41. Bumiaji	0.2313	0.6634	0.116	0.401	Moderate

Figure 5.1 shows spatial distribution of normalized indicators according to classification in Table 5.3.

Table 5.3 Indicators of climate change exposure level on agriculture sector in Greater Malang

No	Level of Exposure	Exposure Indices
1	Weighting 1, Very Low Exposure	0.00 - 0.20
2	Weighting 2, Low Exposure	0.21 – 0.40
3	Weighting 3, Moderate Exposure	0.41 - 0.60
4	Weighting 4, High Exposure	0.61 - 0.80
5	Weighting 5, Very High Exposure	0.81 – 1.00

Based on the result of exposure analysis in Table 5.1, the exposure level of climate change on agriculture sector in Greater Malang has very low, low, and moderate exposure levels except for Donomulyo, Bantur, Sumbermanjing, and Poncokusumo (very high exposure) and Kalipere, Gedangan, and Singosari (high exposure). Generally, urban regions do not have exposure potential because the agricultural lands are small and there are low number of farmers.

Table 5.2 and Figure 5.1 show that the exposure levels are varied between locations in 2030. Most of the sub-districts have very low, low, and moderate exposure levels, except for Donomulyo, Bantur, Sumbermanjing, and Poncokusumo (very high exposure) and Gedangan, and Singosari (high exposure). Sub-distric of Donomulyo, Bantur, Sumbermanjing, and Poncokusumo have a very high level of exposure in 2030 due to more extensive agriculture land and more number of farmers. In general, urban areas have low level of exposure because of narrower agricultural areas and less number of farmers.

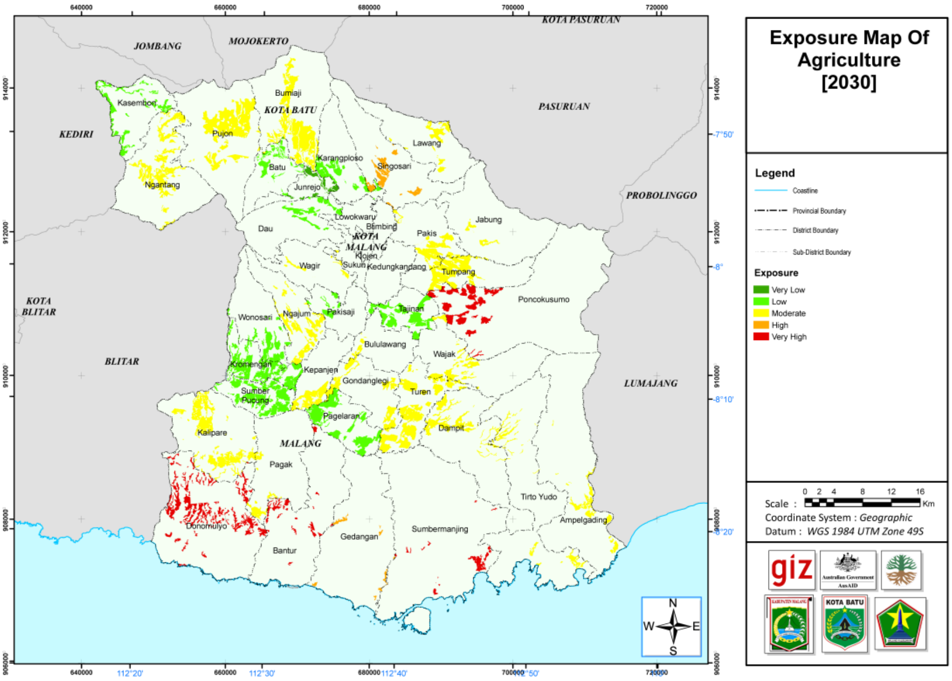


Figure 5.1Map of 2030 Exposure

5.2.2 Sensitivity (S)

In the climate change sensitivity assessment of agriculture sector in Greater Malang, we use three indicators; agricultural land types (non-irrigated lands), topography (elevation), and farmers' income. The result of sensitivity analysis is shown in Table 5.4and Table 5.5. The sensitivity levels of 2030 are shown in Figure 5.2.

Table 5.4 The result of climate change sensitivity (S) analysis to agriculture sector in Greater Malang (2010)

Sub-District	Indicators			Total S	Index of S	Level of Sensitivity
	NIF	A	FI			
01. Donomulyo	0.9500	0.6543	0.5702	0.295	0.861	Very High
02. Kalipare	1.0000	0.7614	0.9167	0.343	1.000	Very High
03. Pagak	1.0000	0.5689	0.2815	0.274	0.799	High
04. Bantur	0.9700	0.7898	0.5293	0.308	0.898	Very High
05. Gedangan	1.0000	0.5797	0.4404	0.288	0.840	Very High
06. Sumbermanjing	0.9800	0.5666	0.2155	0.264	0.771	High
07. Dampit	0.8800	0.5497	0.7857	0.289	0.843	Very High
08. Tirtoyudo	0.9600	0.5358	0.3377	0.268	0.781	High

Sub-District	Indicators			Total S	Index of S	Level of Sensitivity
	NIF	A	FI			
09. Ampelgading	0.9700	0.5828	0.1478	0.258	0.754	High
10. Poncokusumo	0.8800	0.3518	0.3609	0.237	0.691	High
11. Wajak	0.8300	0.5743	1.0000	0.299	0.871	Very High
12. Turen	0.5000	0.6574	0.5524	0.204	0.595	Moderate
13. Bululawang	0.4800	0.6728	0.2605	0.178	0.518	Moderate
14. Gondanglegi	0.3800	0.6590	0.2604	0.156	0.456	Moderate
15. Pagelaran	0.2300	0.6636	0.6152	0.156	0.454	Moderate
16. Kepanjen	0.2900	0.7421	0.6027	0.174	0.506	Moderate
17. Sumberpucung	0.1300	0.7760	0.8747	0.167	0.486	Moderate
18. Kromengan	0.3900	0.7529	0.8158	0.212	0.618	High
19. Ngajum	0.8200	0.7052	0.5488	0.272	0.793	High
20. Wonosari	0.9400	0.3757	0.2980	0.246	0.718	High
21. Wagir	0.7600	0.6351	0.2617	0.230	0.672	High
22. Pakisaji	0.3100	0.7028	0.3727	0.155	0.453	Moderate
23. Tajinan	0.6900	0.6259	0.6541	0.247	0.721	High
24. Tumpang	0.6900	0.5558	0.4014	0.221	0.643	High
25. Pakis	0.5200	0.6351	0.2767	0.184	0.536	Moderate
26. Jabung	0.7500	0.5196	0.4989	0.237	0.692	High
27. Lawang	0.8800	0.5943	0.2975	0.254	0.740	High
28. Singosari	0.7000	0.6205	0.3491	0.224	0.654	High
29. Karangploso	0.6500	0.5681	0.6339	0.232	0.678	High
30. Dau	0.8800	0.5674	0.1784	0.242	0.705	High
31. Pujon	0.7700	0.0000	0.2200	0.172	0.501	Moderate
32. Ngantang	0.8100	0.3303	0.4788	0.231	0.672	High
33. Kasembon	0.8700	0.8152	0.9477	0.324	0.946	Very High
34. Kedungkandang	0.6428	0.5781	0.2900	0.204	0.595	Moderate
35. Sukun	0.5515	0.5781	0.2960	0.186	0.544	Moderate
36. Klojen	0.0000	0.5781	0.0000	0.052	0.152	Very Low
37. Blimbing	0.0340	0.6374	0.0847	0.071	0.207	Low
38. Lowokwaru	0.2083	0.6459	0.2414	0.119	0.348	Low
39. Batu	0.5717	0.3680	0.1283	0.158	0.461	Moderate
40. Junrejo	0.3772	0.4696	0.3083	0.143	0.416	Moderate
41. Bumiaji	0.5351	0.1824	0.1230	0.133	0.389	Low

Notes: NIF : Non-irrigated Fields (expressed as indices range 0-1
A: Elevation (expressed as indices range 0-1)
FI: Farmers' Income (expressed as indices range 0-1)
S: Sensitivity (expressed as indices range 0-1)

Table 5.5 The Projection of climate change sensitivity (S) on agriculture sector in Greater Malang (2030)

Sub-District	Indicator			Total S	Index of S	Level of Sensitivity
	NIF	A	FI			
01. Donomulyo	0.0091	0.6543	0.6001	0.109	0.333	Low
02. Kalipare	0.0502	0.7614	0.8810	0.150	0.457	Moderate
03. Pagak	0.0032	0.5689	0.2699	0.074	0.225	Low
04. Bantur	0.3169	0.7898	0.5084	0.176	0.535	Moderate
05. Gedangan	0.6802	0.5797	0.3908	0.220	0.670	High

Sub-District	Indicator			Total S	Index of S	Level of Sensitivity
	NIF	A	FI			
06. Sumbermanjing	0.7737	0.5666	0.2024	0.222	0.677	High
07. Dampit	1.0000	0.5497	0.7588	0.311	0.947	Very High
08. Tirtoyudo	1.0000	0.5358	0.3273	0.275	0.837	Very High
09. Ampelgading	0.9938	0.5828	0.1412	0.263	0.800	Very High
10. Poncokusumo	1.0000	0.3518	0.3201	0.258	0.785	High
11. Wajak	0.8248	0.5743	1.0000	0.298	0.907	Very High
12. Turen	0.8271	0.6574	0.5168	0.266	0.812	Very High
13. Bululawang	1.0000	0.6728	0.2484	0.281	0.855	Very High
14. Gondanglegi	1.0000	0.6590	0.1717	0.273	0.832	Very High
15. Pagelaran	1.0000	0.6636	0.5951	0.308	0.938	Very High
16. Kepanjen	1.0000	0.7421	0.7583	0.328	1.000	Very High
17. Sumberpucung	0.9669	0.7760	0.4107	0.296	0.903	Very High
18. Kromengan	0.4686	0.7529	0.7829	0.225	0.685	High
19. Ngajum	0.9524	0.7052	0.5185	0.296	0.902	Very High
20. Wonosari	0.7709	0.3757	0.2990	0.212	0.647	High
21. Wagir	1.0000	0.6351	0.2401	0.277	0.843	Very High
22. Pakisaji	0.8681	0.7028	0.3562	0.266	0.810	Very High
23. Tajinan	1.0000	0.6259	0.6114	0.306	0.932	Very High
24. Tumpang	1.0000	0.5558	0.3833	0.281	0.856	Very High
25. Pakis	1.0000	0.6351	0.2471	0.277	0.844	Very High
26. Jabung	1.0000	0.5196	0.4727	0.285	0.869	Very High
27. Lawang	0.7859	0.5943	0.2910	0.234	0.714	High
28. Singosari	0.9898	0.6205	0.3209	0.280	0.852	Very High
29. Karangploso	1.0000	0.5681	0.6244	0.302	0.919	Very High
30. Dau	1.0000	0.5674	0.1741	0.265	0.808	Very High
31. Pujon	0.0039	0.0000	0.2155	0.018	0.056	Very Low
32. Ngantang	0.7359	0.3303	0.4461	0.213	0.649	High
33. Kasembon	0.0373	0.8152	0.8854	0.153	0.465	Moderate
34. Kedungkandang	0.6428	0.5781	0.2555	0.201	0.613	High
35. Sukun	0.5515	0.5781	0.2202	0.180	0.549	Moderate
36. Klojen	0.0000	0.5781	0.0000	0.052	0.159	Very Low
37. Blimbing	0.0340	0.6374	0.0631	0.069	0.211	Low
38. Lowokwaru	0.2083	0.6459	0.1975	0.116	0.353	Low
39. Batu	0.5717	0.3680	0.1010	0.156	0.474	Moderate
40. Junrejo	0.3772	0.4696	0.2421	0.137	0.418	Moderate
41. Bumiaji	0.5351	0.1824	0.0996	0.132	0.401	Moderate

Notes: NIF : Non-irrigated Fields;
A: Elevation;
FI: Farmers' Income;
S: Sensitivity

Sensitivity indicators for 2010 and 2030 are respectively shown in Figure 5.2 according to classification in Table 5.6

Table 5.6Indicators of climate change sensitivity level on agriculture sector in Greater Malang

No	Level of Sensitivity	Sensitivity Index
1	Weighting 1, Sensitivity Very Low	0.00 - 0.20
2	Weighting 2, Sensitivity Low	0.21 – 0.40
3	Weighting 3, Sensitivity Moderate	0.41 - 0.60
4	Weighting 4, Sensitivity High	0.61 - 0.80
5	Weighting 5, Sensitivity Very High	0.81 – 1.00

Based on the result of sensitivity analysis in Table 5.4, climate change sensitivity on agriculture sector in Greater Malang is dominated by very high, high, and moderate sensitivity; except for Klojen with very low sensitivity; Blimbing, Lowokwaru, and Bumiaji with low sensitivity. In sub-districts with many non-irrigated agriculture fields, flat lowland areas, and low farmers' income, the sensitivity potential is very high. Generally, Greater Malang has a very high sensitivity potential due to its large area of non-irrigated agricultural fields, flat lowland areas, and also low farmers' income.

The projection of sensitivity in Table 5.5and Figure 5.2 show that the sensitivity level on agriculture sector is dominated by the very high, high, and moderate level sensitivity, except for Pujon and Klojen with very low sensitivity; and Donomulyo, Pagak, Blimbing, and Lowokwaru with low sensitivity. Sub-districts with large area of non-irrigated lands, low plains, and low farmers' income have very high sensitivity potential. In general, Greater Malang has high and very high levels of sensitivity due to its large area of non-irrigated lands, low plains, and low farmers' income.

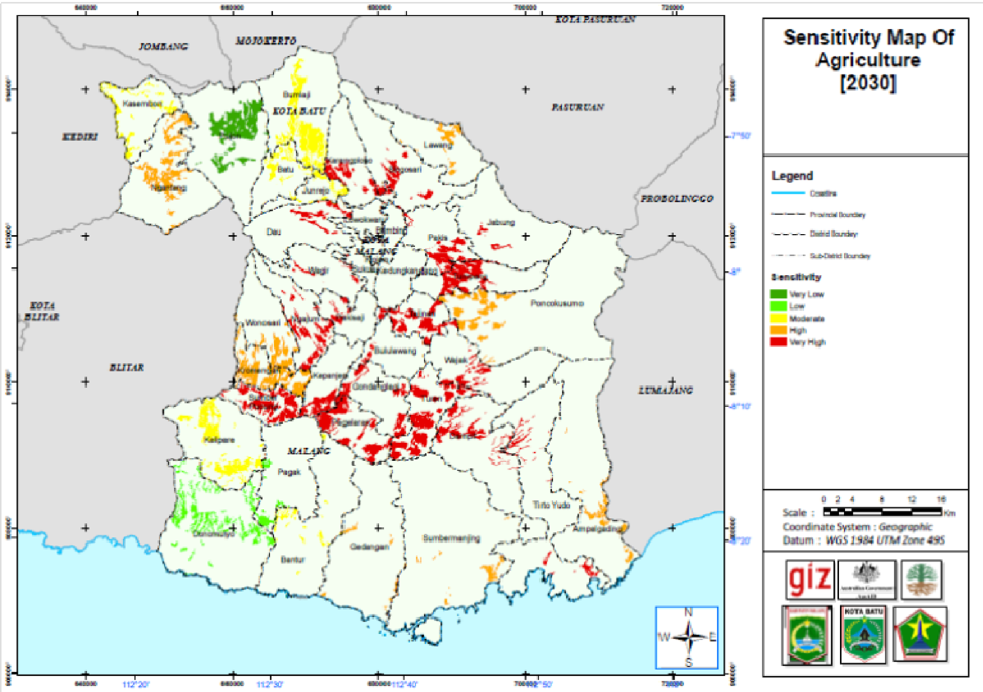


Figure 5.2 Map of 2030 Sensitivity

5.2.3 Adaptive Capacity (AC)

Climate change adaptive capacity assessment on agriculture sector in Greater Malang uses three indicators; irrigation infrastructures, education level, and access to capital. The result of this analysis is shown in Table 5.7 and Table 5. **8.** Meanwhile, the 2030 adaptive capacity levels are shown in Figure 5.3.

Table 5.7 The result of climate change adaptive capacity (AC) analysis of agriculture sector in Greater Malang (2010)

Sub-District	Indicators			Total AC	Index of AC	Adaptive Capacity Levels
	II	EL	ATC			
01. Donomulyo	0.0518	0.7063	0.0618	0.063	0.195	Very Low
02. Kalipare	0.0000	0.7061	0.0562	0.052	0.161	Very Low
03. Pagak	0.0000	0.7061	0.0562	0.052	0.161	Very Low
04. Bantur	0.0311	0.7061	0.0562	0.058	0.181	Very Low
05. Gedangan	0.0000	0.7065	0.0449	0.051	0.159	Very Low
06. Sumbermanjing	0.0207	0.7061	0.0899	0.058	0.179	Very Low
07. Dampit	0.1242	0.7061	0.2865	0.088	0.273	Low
08. Tirtoyudo	0.0414	0.7063	0.0337	0.060	0.184	Very Low
09. Ampelgading	0.0311	0.7062	0.0337	0.057	0.178	Very Low
10. Poncokusumo	0.1242	0.7064	0.1011	0.080	0.247	Low
11. Wajak	0.1760	0.7061	0.0955	0.091	0.280	Low

Sub-District	Indicators			Total AC	Index of AC	Adaptive Capacity Levels
	II	EL	ATC			
12. Turen	0.5176	0.7060	0.2191	0.167	0.518	Moderate
13. Bululawang	0.5383	0.7062	0.2022	0.171	0.529	Moderate
14. Gondanglegi	0.6418	0.7058	0.2416	0.194	0.601	High
15. Pagelaran	0.7971	0.7062	0.0674	0.219	0.677	High
16. Kepanjen	0.7350	0.7059	0.6348	0.232	0.716	High
17. Sumberpucung	0.9006	0.7060	0.1798	0.246	0.760	High
18. Kromengan	0.6315	0.7061	0.0449	0.183	0.567	Moderate
19. Ngajum	0.1863	0.7062	0.0225	0.089	0.276	Low
20. Wonosari	0.0621	0.7062	0.0562	0.065	0.201	Low
21. Wagir	0.2485	0.7065	0.0787	0.105	0.324	Low
22. Pakisaji	0.7143	0.7063	0.2135	0.208	0.644	High
23. Tajinan	0.3209	0.7060	0.0843	0.120	0.372	Low
24. Tumpang	0.3209	0.7059	0.2528	0.128	0.395	Low
25. Pakis	0.4969	0.7062	0.2640	0.165	0.511	Moderate
26. Jabung	0.2588	0.7064	0.0506	0.106	0.327	Low
27. Lawang	0.1242	0.7062	0.3764	0.092	0.285	Low
28. Singosari	0.3106	0.7062	0.5169	0.138	0.425	Moderate
29. Karangploso	0.3623	0.7060	0.2303	0.136	0.419	Moderate
30. Dau	0.1242	0.7061	0.1854	0.084	0.259	Low
31. Pujon	0.2381	0.7065	0.0955	0.104	0.320	Low
32. Ngantang	0.1967	0.7065	0.0618	0.093	0.289	Low
33. Kasembon	0.1346	0.7065	0.0562	0.080	0.248	Low
34. Kedungkandang	0.3698	0.9933	1.0000	0.192	0.593	Moderate
35. Sukun	0.4643	0.9933	1.0000	0.212	0.654	High
36. Klojen	0.0000	0.9933	1.0000	0.115	0.354	Low
37. Blimbing	1.0000	0.9933	1.0000	0.324	1.000	Very High
38. Lowokwaru	0.8206	0.9933	1.0000	0.286	0.884	Very High
39. Batu	0.4434	1.0000	0.6854	0.194	0.598	Moderate
40. Junrejo	0.6447	1.0000	0.1910	0.213	0.659	High
41. Bumiaji	0.4813	1.0000	0.1404	0.177	0.547	Moderate

Notes : II : Irrigation Infrastructure (expressed as indices indices range 0-1)
EL: Education Level (expressed as indices range 0-1)
ATC : Access to The Capital (expressed as indices indices range 0-1)
AC: Adaptive Capasity (expressed as indices indices range 0-1)

Table 5. 8 Projection of climate change adaptive capacity (AC) on agriculture in Greater Malang (2030)

Sub-Districts	Indicators			Total AC	Index of AC	Adaptive Capacity Levels
	II	EL	ATC			
01. Donomulyo	0.9941	0.8369	0.0738	0.270	0.902	Very High
02. Kalipare	0.9528	0.7640	0.0613	0.255	0.855	Very High
03. Pagak	1.0000	0.7624	0.0611	0.265	0.887	Very High
04. Bantur	0.6853	0.7636	0.0612	0.199	0.667	High
05. Gedangan	0.3208	0.7059	0.0453	0.119	0.397	Low
06. Sumbermanjing	0.2270	0.7467	0.0958	0.104	0.348	Low
07. Dampit	0.0000	0.7678	0.3140	0.068	0.227	Low
08. Tirtoyudo	0.0000	0.7709	0.0371	0.056	0.186	Very Low

Sub-Districts	Indicators			Total AC	Index of AC	Adaptive Capacity Levels
	II	EL	ATC			
09. Ampelgading	0.0062	0.7599	0.0366	0.056	0.188	Very Low
10. Poncokusumo	0.0000	0.7055	0.1018	0.054	0.181	Very Low
11. Wajak	0.1758	0.7950	0.1084	0.097	0.325	Low
12. Turen	0.1734	0.7437	0.2326	0.099	0.330	Low
13. Bululawang	0.0000	0.7581	0.2188	0.063	0.211	Low
14. Gondanglegi	0.0000	0.5238	0.1807	0.045	0.150	Very Low
15. Pagelaran	0.0000	0.7691	0.0740	0.057	0.191	Very Low
16. Kepanjen	0.0000	1.0000	0.9064	0.111	0.371	Low
17. Sumberpucung	0.0332	0.3732	0.0958	0.037	0.125	Very Low
18. Kromengan	0.5331	0.7630	0.0489	0.167	0.559	Moderate
19. Ngajum	0.0477	0.7513	0.0241	0.064	0.213	Low
20. Wonosari	0.2298	0.7978	0.0640	0.107	0.357	Low
21. Wagir	0.0000	0.7297	0.0819	0.055	0.183	Very Low
22. Pakisaji	0.1323	0.7601	0.2315	0.091	0.305	Low
23. Tajinan	0.0000	0.7431	0.0894	0.056	0.188	Very Low
24. Tumpang	0.0000	0.7589	0.2739	0.065	0.219	Low
25. Pakis	0.0000	0.7103	0.2676	0.062	0.207	Low
26. Jabung	0.0000	0.7537	0.0544	0.055	0.185	Very Low
27. Lawang	0.2148	0.7778	0.4178	0.118	0.395	Low
28. Singosari	0.0102	0.7309	0.5391	0.078	0.260	Low
29. Karangploso	0.0000	0.7829	0.2574	0.066	0.222	Low
30. Dau	0.0000	0.7762	0.2054	0.064	0.213	Low
31. Pujon	0.9993	0.7795	0.1062	0.268	0.897	Very High
32. Ngantang	0.2649	0.7412	0.0653	0.110	0.369	Low
33. Kasembon	0.9658	0.7432	0.0596	0.257	0.859	Very High
34. Kedungkandang	0.3583	0.9856	1.0000	0.189	0.632	High
35. Sukun	0.4499	0.8319	0.8440	0.190	0.637	High
36. Klojen	0.0000	0.7115	0.7219	0.082	0.275	Low
37. Blimbing	0.9691	0.8327	0.8448	0.299	1.000	Very High
38. Lowokwaru	0.7952	0.9150	0.9284	0.272	0.910	Very High
39. Batu	0.4297	0.8867	0.6125	0.179	0.600	High
40. Junrejo	0.6248	0.8840	0.1702	0.200	0.670	High
41. Bumiaji	0.4664	0.9120	0.1291	0.167	0.559	Moderate

Notes : II : Irrigation Infrastructure (expressed as indices indices range 0-1)
EL: Education Level (expressed as indices indices range 0-1)
ATC : Access to The Capital (expressed as indices indices range 0-1)
AC: Adaptive Capacity (expressed as indices indices range 0-1)

Indicators of adaptive capacity for 2030 are presented in Figure 5.3 according to classification shown in Table 5.9.

Table 5.9 Climate change sensitivity level on agriculture sector in Greater Malang

No	Adaptive Capacity Levels	Indices
1	Weighting 1, very low adaptive capacity potential	0.00 - 0.20
2	Weighting 2, low adaptive capacity potential	0.21 – 0.40
3	Weighting 3, moderate adaptive capacity potential	0.41 - 0.60
4	Weighting 4, high adaptive capacity potential	0.61 - 0.80
5	Weighting 5, very high adaptive capacity potential	0.81 – 1.00

The results of adaptive capacity analysis in Table 5.7 show that the climate change adaptive capacity of agriculture sector in Greater Malang is generally very low, low, and moderate levels, except for Blimbing and Lowokwaru that have very high adaptive capacity and Bantur, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Pakisaji, Sukun, and Junrejo that have high adaptive capacity. In sub-districts which have low irrigation infrastructures, farmers' education level, and access to the capital, the adaptive capacity potential is very low. Generally, Greater Malang has low and very low adaptive capacity due to its relatively low irrigation infrastructures, farmers' education level, and access to the capital.

The projection of adaptive capacity (Table 5. **8** and Figure 5.3) shows that the levels are dominated by the very low, low, and moderate level adaptive capacity, except for Donomulyo, Kalipare, Pagak, Pujon, Kasembon, Blimbing and Lowokwaru that have very high adaptive capacity and Bantur, Kedungkandang. Sukun, Batu, and Junrejo that have high adaptive capacity

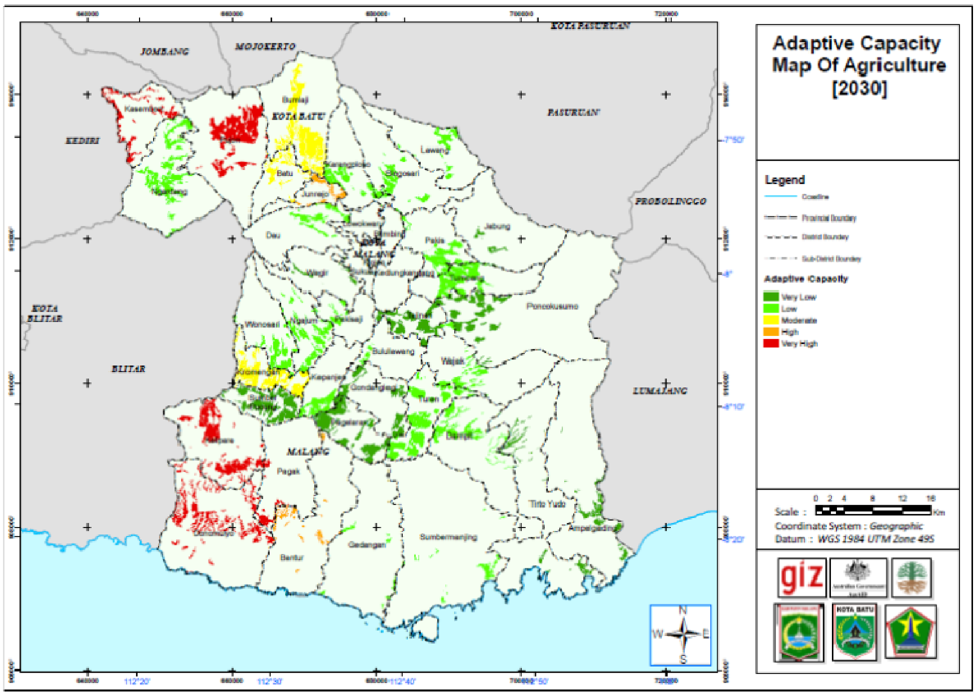


Figure 5.3 Map of 2030 Adaptive Capacity

5.2.4 Vulnerability

Climate change vulnerability assessment on agriculture sector in Greater Malang is a combination of three vulnerability components that have already been presented; they are exposure (E), sensitivity (S), and adaptive capacity (AC). The result of vulnerability analysis is presented in Table 5.10 and Table 5.11. Meanwhile, the 2030 vulnerabilities are shown in Figure 5.4 and Figure 5. **5**.

Table 5.10 The result of climate change vulnerability (V) analysis to agriculture sector in Greater Malang (2010)

Sub-District	Indicators			Total V	Index of V	Level of Vulnerability
	E	S	AC			
01. Donomulyo	0.265	0.295	0.063	2.065	1.000	Very High
02. Kalipare	0.159	0.343	0.052	1.914	0.927	Very High
03. Pagak	0.149	0.274	0.052	1.786	0.865	Very High
04. Bantur	0.243	0.308	0.058	2.048	0.992	Very High
05. Gedangan	0.183	0.288	0.051	1.899	0.919	Very High
06. Sumbermanjing	0.244	0.264	0.058	1.984	0.961	Very High
07. Dampit	0.144	0.289	0.088	1.783	0.863	Very High
08. Tirtoyudo	0.122	0.268	0.060	1.688	0.817	Very High

Sub-District	Indicators			Total V	Index of V	Level of Vulnerability
	E	S	AC			
09. Ampelgading	0.149	0.258	0.057	1.759	0.852	Very High
10. Poncokusumo	0.226	0.237	0.080	1.894	0.917	Very High
11. Wajak	0.158	0.299	0.091	1.834	0.888	Very High
12. Turen	0.155	0.204	0.167	1.631	0.790	High
13. Bululawang	0.117	0.178	0.171	1.446	0.700	High
14. Gondanglegi	0.148	0.156	0.194	1.485	0.719	High
15. Pagelaran	0.106	0.156	0.219	1.329	0.643	High
16. Kepanjen	0.126	0.174	0.232	1.448	0.701	High
17. Sumberpucung	0.078	0.167	0.246	1.216	0.589	Moderate
18. Kromengan	0.084	0.212	0.183	1.374	0.665	High
19. Ngajum	0.121	0.272	0.089	1.679	0.813	Very High
20. Wonosari	0.061	0.246	0.065	1.350	0.653	High
21. Wagir	0.139	0.230	0.105	1.661	0.804	Very High
22. Pakisaji	0.099	0.155	0.208	1.305	0.632	High
23. Tajinan	0.095	0.247	0.120	1.519	0.736	High
24. Tumpang	0.134	0.221	0.128	1.617	0.783	High
25. Pakis	0.152	0.184	0.165	1.577	0.763	High
26. Jabung	0.141	0.237	0.106	1.679	0.813	Very High
27. Lawang	0.134	0.254	0.092	1.691	0.819	Very High
28. Singosari	0.181	0.224	0.138	1.752	0.848	Very High
29. Karangploso	0.103	0.232	0.136	1.522	0.737	High
30. Dau	0.092	0.242	0.084	1.511	0.731	High
31. Pujon	0.107	0.172	0.104	1.418	0.687	High
32. Ngantang	0.110	0.231	0.093	1.565	0.758	High
33. Kasembon	0.072	0.324	0.080	1.535	0.743	High
34. Kedungkandang	0.055	0.204	0.192	1.175	0.569	Moderate
35. Sukun	0.035	0.186	0.212	0.924	0.447	Moderate
36. Klojen	0.014	0.052	0.115	0.004	0.002	Very Low
37. Blimbing	0.022	0.071	0.324	0.265	0.128	Very Low
38. Lowokwaru	0.028	0.119	0.286	0.617	0.299	Low
39. Batu	0.066	0.158	0.194	1.137	0.550	Moderate
40. Junrejo	0.043	0.143	0.213	0.902	0.437	Moderate
41. Bumiaji	0.116	0.133	0.177	1.319	0.639	High

Notes: E : Exposure (expressed as indices indices range 0-1)
S: Sensitivity (expressed as indices indices range 0-1)
AC: Adaptive Capacity (expressed as indices indices range 0-1)

Table 5.11 Projection of climate change vulnerability (V) on agriculture sector in Greater Malang (2030)

Sub-District	Indicators			Total V	Index of V	Level of Vulnerability
	E	S	AC			
01. Donomulyo	0.271	0.109	0.270	1.711	0.822	Very High
02. Kalipare	0.161	0.150	0.255	1.627	0.782	High
03. Pagak	0.150	0.074	0.265	1.283	0.617	High
04. Bantur	0.245	0.176	0.199	1.897	0.912	Very High
05. Gedangan	0.182	0.220	0.119	1.896	0.911	Very High

Sub-District	Indicators			Total V	Index of V	Level of Vulnerability
	E	S	AC			
06. Sumbermanjing	0.245	0.222	0.104	2.036	0.978	Very High
07. Dampit	0.148	0.311	0.068	1.976	0.950	Very High
08. Tirtoyudo	0.124	0.275	0.056	1.852	0.890	Very High
09. Ampelgading	0.150	0.263	0.056	1.914	0.920	Very High
10. Poncokusumo	0.224	0.258	0.054	2.081	1.000	Very High
11. Wajak	0.162	0.298	0.097	1.985	0.954	Very High
12. Turen	0.156	0.266	0.099	1.920	0.923	Very High
13. Bululawang	0.118	0.281	0.063	1.836	0.882	Very High
14. Gondanglegi	0.135	0.273	0.045	1.891	0.909	Very High
15. Pagelaran	0.108	0.308	0.057	1.839	0.884	Very High
16. Kepanjen	0.145	0.328	0.111	1.976	0.949	Very High
17. Sumberpucung	0.063	0.296	0.037	1.596	0.767	High
18. Kromengan	0.085	0.225	0.167	1.555	0.747	High
19. Ngajum	0.122	0.296	0.064	1.873	0.900	Very High
20. Wonosari	0.064	0.212	0.107	1.429	0.687	High
21. Wagir	0.139	0.277	0.055	1.904	0.915	Very High
22. Pakisaji	0.101	0.266	0.091	1.733	0.833	Very High
23. Tajinan	0.095	0.306	0.056	1.783	0.857	Very High
24. Tumpang	0.136	0.281	0.065	1.896	0.911	Very High
25. Pakis	0.150	0.277	0.062	1.934	0.930	Very High
26. Jabung	0.142	0.285	0.055	1.927	0.926	Very High
27. Lawang	0.137	0.234	0.118	1.801	0.865	Very High
28. Singosari	0.181	0.280	0.078	2.016	0.969	Very High
29. Karangploso	0.105	0.302	0.066	1.815	0.872	Very High
30. Dau	0.094	0.265	0.064	1.713	0.823	Very High
31. Pujon	0.109	0.018	0.268	0.537	0.258	Low
32. Ngantang	0.111	0.213	0.110	1.670	0.802	Very High
33. Kasembon	0.073	0.153	0.257	1.287	0.619	High
34. Kedungkandang	0.055	0.201	0.189	1.309	0.629	High
35. Sukun	0.031	0.180	0.190	1.013	0.487	Moderate
36. Klojen	0.009	0.052	0.082	0.001	0.000	Very Low
37. Blimbing	0.018	0.069	0.299	0.329	0.158	Very Low
38. Lowokwaru	0.026	0.116	0.272	0.718	0.345	Low
39. Batu	0.060	0.156	0.179	1.244	0.598	Moderate
40. Junrejo	0.041	0.137	0.200	1.011	0.486	Moderate
41. Bumiaji	0.109	0.132	0.167	1.430	0.687	High

Notes: E : Exposure (expressed as indices indices range 0-1)
S: Sensitivity (expressed as indices indices range 0-1)
AC: Adaptive Capacity (expressed as indices indices range 0-1)
V: Vulnerability (expressed as indices indices range 0-1)

Indicators of vulnerability for 2030 are presented in Figure 5.4and Figure 5. **5** according to classification in Table 5.12.

Table 5.12 Indicators of climate change vulnerability levels on agriculture sector in Greater Malang

No	Level of Vulnerability	Vulnerability Indices
1	Weighting 1, Very Low Vulnerability	0.00 - 0.20
2	Weighting 2, Low Vulnerability	0.21 – 0.40
3	Weighting 3, Moderate Vulnerability	0.41 - 0.60
4	Weighting 4, High Vulnerability	0.61 - 0.80
5	Weighting 5, Very High Vulnerability	0.81 – 1.00

Table 5.10shows that the vulnerability levels are varied and dominated by very high and high levels. Except for sub-district of Klojen and Blimbing that have very low vulnerability level; Lowokwaru has low vulnerability level; while Sumberpucung, Kedungkandang, Sukun, Batu, and Junrejo have moderate level of vulnerability.

The projection of vulnerability in Table 5.11 shows that some areas are still dominated by high and very high vulnerability levels, while Lowokwaru has very low or low level of vulnerability. There are only three sub-districts, Sukun, Batu, and Junrejo, which have moderate vulnerability level.

Based on the results of vulnerability and projection analysis for 2030, most parts of Greater Malang do not experience vulnerability change, such as in Donomulyo, Bantur, Gedangan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Poncokusumo, Wajak, Kromengan, Ngajum, Wonosari, Wagir, Jagung, Lawang, Singosari, Kasembon, Sukun, Klojen, Blimbing, Lowokwaru, Batu, Junrejo, and Bumiaji (Table 5.10 and Table 5.11). However, other parts experience change such as Pujon (high to low); Kalipare and Pagak (very high to high); Sumberpucung and Kedungkandang (moderate to high); and Turen, Bululawang, Gondanglegi, Pagelaran, Kepanjen, Pakisaji, Tajinan, Tumpang, Pakis, Karangploso, Dau, and Ngantang (high to very high). Changes in 2030 are mainly related with the dynamical change in non-irrigated regions and irrigation infrsstructures. The summary of these changes are shown in Table 5.13 and Table 5.14.

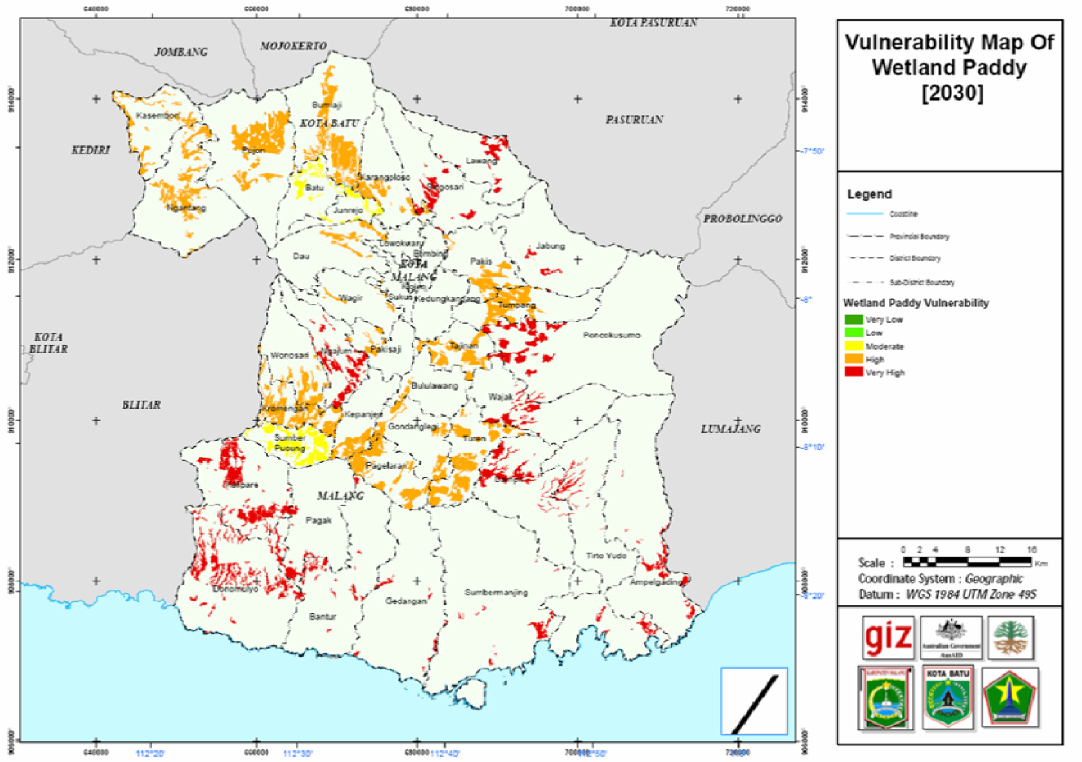


Figure 5.4 Map of 2030 Wetland Paddy Vulnerability

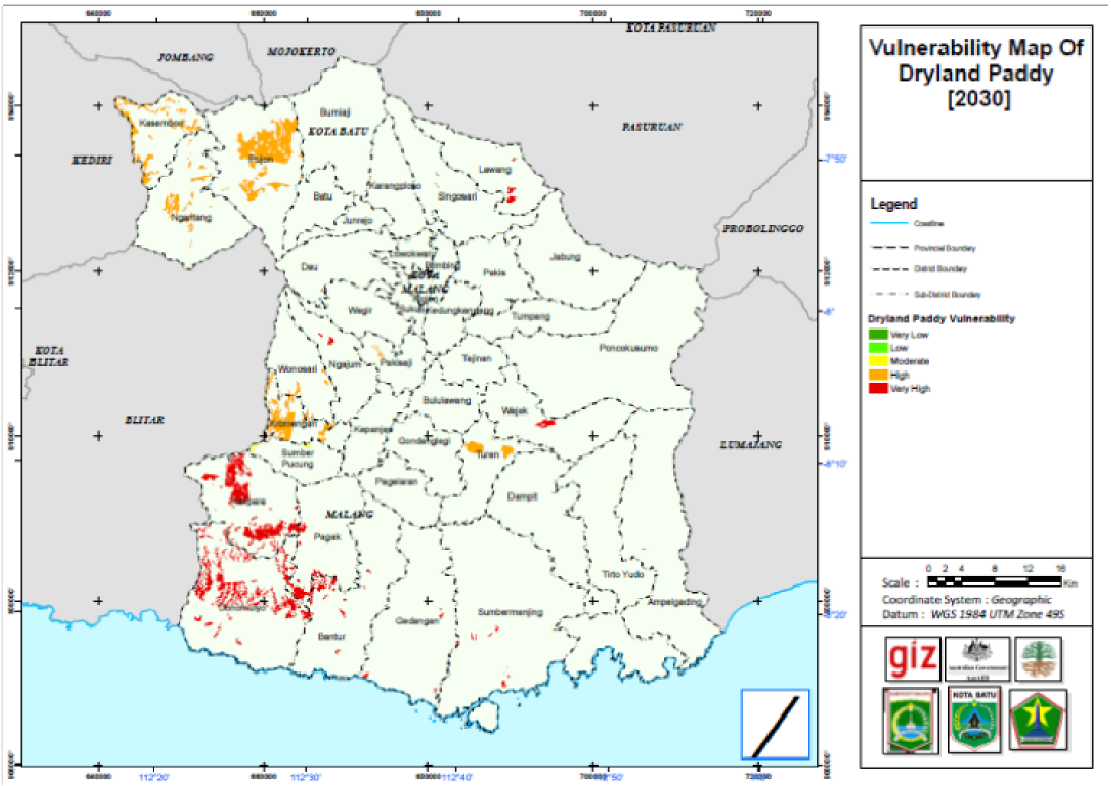


Figure 5. 5 Map of 2030 Dryland Paddy Vulnerability

The results show that Donomulyo, Bantur, Gedangan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Poncokusumo, Wajak, Turen, Bululawang, Gondanglegi, Pagelaran, Kepanjen, Ngajum, Wagir, Pakisaji, Tajinan, Tumpang, Pakis, Jabung, Lawang, Singosari, Karangplos, Kepanjen, Ngajum, Wagir, Pakisaji, Tajinan, Tumpang, Pakis, Jabung, Lawang, Singosari, Karangploso, Dau, and Ngantang are highly vulnerable to climate change. High or very high level of vulnerability indicates that the climate change impact on crop production in Greater Malang would be very high. Therefore, adaptation strategy measures are needed, so that the vulnerability level will not suppress the agricultural production, food availability, and food sufficiency in Greater Malang.

Table 5.13 Summary of vulnerability on agriculture sector in Greater Malang (2010 and 2030)

Sub-District	Level of Vulnerability	
	2010	2030
01. Donomulyo	1.000	0.822
02. Kalipare	0.927	0.782
03. Pagak	0.865	0.617
04. Bantur	0.992	0.912
05. Gedangan	0.919	0.911
06. Sumbermanjing	0.961	0.978
07. Dampit	0.863	0.950
08. Tirtoyudo	0.817	0.890
09. Ampelgading	0.852	0.920
10. Poncokusumo	0.917	1.000
11. Wajak	0.888	0.954
12. Turen	0.790	0.923
13. Bululawang	0.700	0.882
14. Gondanglegi	0.719	0.909
15. Pagelaran	0.643	0.884
16. Kepanjen	0.701	0.949
17. Sumberpucung	0.589	0.767
18. Kromengan	0.665	0.747
19. Ngajum	0.813	0.900
20. Wonosari	0.653	0.687
21. Wagir	0.804	0.915
22. Pakisaji	0.632	0.833
23. Tajinan	0.736	0.857
24. Tumpang	0.783	0.911
25. Pakis	0.763	0.930
26. Jabung	0.813	0.926
27. Lawang	0.819	0.865
28. Singosari	0.848	0.969
29. Karangploso	0.737	0.872
30. Dau	0.731	0.823
31. Pujon	0.687	0.258

Sub-District	Level of Vulnerability	
	2010	2030
32. Ngantang	0.758	0.802
33. Kasembon	0.743	0.619
34. Kedungkandang	0.569	0.629
35. Sukun	0.447	0.487
36. Klojen	0.002	0.000
37. Blimbing	0.128	0.158
38. Lowokwaru	0.299	0.345
39. Batu	0.550	0.598
40. Junrejo	0.437	0.486
41. Bumiaji	0.639	0.687

Table 5.14The distribution of climate change vulnerability on agriculture sector in Greater Malang (2010 and 2030)

Year	Sub-District		
	Moderate Vulnerability	**High Vulnerability**	**Very High Vulnerability**
2010	Sumberpucung, Kedungkandang, Sukun, Batu,and Junrejo	Turen, Bululawang, Gondanglegi, Pagelaran, Kepanjen, Kromengan, Wonosari, Pakisaji, Tajinan, Tumpang, Pakis, Karangploso, Dau, Pujon, Ngantang, Kasembon, and Bumiaji	Donomulyo, Kalipare, Pagak, Bantur, Gedangan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Poncokusumo, Wajak, Ngajum, Wagir, Jabung, Lawang, and Singosari.
2030	Sukun, Batu,and Junrejo	Kalipare, Pagak, Sumberpucung, Kromengan, Wonosari, Kasembon, Kedungkandang, and Bumiaji	Donomulyo, Bantur, Gedangan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Poncokusumo, Wajak, Turen, Bululawang, Gondanglegi, Pagelaran, Kepanjen, Ngajum, Wagir, Pakisaji, Tajinan, Tumpang, Pakis, Jabung, Lawang, Singosari, Karangploso, Dau, and Ngantang

Chapter VI RISK ASSESSMENT IN AGRICULTURE SECTOR DUE TO CLIMATE CHANGE

6.1 Risk Assessment in Agriculture Sector

In the agriculture sector, risk concept can be interpreted as a possibility which can lead to loss represented by a decline in food crop production as hazard. Furthermore, the hazard of decreasing production may lead to direct or indirect welfare decline of farmers and reduction of food supply, which is a part of food security in Greater Malang. Decreasing crop production is considered as a climate change hazard in this analysis.

The climate change risk is calculated using the following equation:

$$R = H\ V$$

R = Risk,

H = Hazard, calculated from the decrease in agricultural production (Eq. 1 to 16),

V = Vulnerability, from previous equation (Eq. 17).

Climate change risk analysis on agriculture sector is based on the baseline and projection scenario of SRA1B to calculate H. Risk (R) for each sub-districts in Greater Malang was mapped spatially to show where the most vulnerable to least vulnerable as the basis for adaption analysis.

The result of risk analysis shows, based on those spatial factors, different levels of hazard and vulnerability in each sub-districts in Greater Malang. Risk analysis of decreasing productivity, harvested area, and production is conducted for two main commodity crops (paddy and corn) in Greater Malang. The risk is divided into five levels; very low, low, moderate, high, and very high. Risk indicators are represented by the green, blue, yellow, orange, and red colours, respectively, as shown in Figure 6.1 and Figure 6.2. The classification and weighting factors are shown in Table 6.1.

Table 6.1 The risk level of indicators in decreasing productivity, harvest area, and staple food crops' production up to 2030 in Greater Malang.

.No	Level of Risk	Risk Index
1	Weighting 1, Very Low Risk	< 0.200
2	Weighting 2, Low Risk	0.200 – 0.400
3	Weighting 3, Moderate Risk	0.400- 0.600
4	Weighting 4, High Risk	0.600 - 0.800
5	Weighting 1, Very High Risk	>0.800

6.2 Risk of Decreasing Food Crops Productivity

The risk analysis results of decreasing productivity of staple food crops, namely paddy and corn in Greater Malang are shown in Table 6.2.

Table 6.2 Risk Analysis Result of Decreasing Productivity of Wetland Paddy Field, Dryland Paddy Field, and Corn up to 2030 in Greater Malang

Sub-Districs	Level of Risk		
	Wetland Paddy	Dryland Paddy	Corn
01. Donomulyo	0.529	0.588	0.529
02. Kalipare	0.538	0.541	0.524
03. Pagak	0.404	0.449	0.455
04. Bantur	0.613	0.769	0.708
05. Gedangan	0.613	0.759	0.703
06. Sumbermanjing	0.689	0.800	0.763
07. Dampit	0.677	0.826	0.737
08. Tirtoyudo	0.599	0.780	0.707
09. Ampelgading	0.577	0.000	0.696
10. Poncokusumo	0.707	0.788	0.990
11. Wajak	0.843	0.855	0.857
12. Turen	0.820	0.743	0.938
13. Bululawang	0.622	0.699	0.751
14. Gondanglegi	0.860	0.000	0.959
15. Pagelaran	0.839	0.000	0.869
16. Kepanjen	0.844	0.000	0.877
17. Sumberpucung	0.632	0.000	0.813
18. Kromengan	0.500	0.000	0.542
19. Ngajum	0.656	0.626	0.806
20. Wonosari	0.470	0.448	0.553
21. Wagir	0.652	0.638	0.676
22. Pakisaji	0.616	0.000	0.690
23. Tajinan	0.581	0.597	0.733
24. Tumpang	0.672	0.000	0.790
25. Pakis	0.869	0.000	1.000
26. Jabung	0.699	0.703	0.853
27. Lawang	0.820	0.000	0.739
28. Singosari	1.000	1.000	0.919
29. Karangploso	0.669	0.712	0.707
30. Dau	0.595	0.570	0.687
31. Pujon	0.169	0.000	0.231
32. Ngantang	0.556	0.000	0.693

Sub-Districs	Level of Risk		
	Wetland Paddy	Dryland Paddy	Corn
33. Kasembon	0.424	0.412	0.510
34. Kedungkandang	0.498	0.000	0.418
35. Sukun	0.439	0.000	0.317
36. Klojen	0.000	0.000	0.000
37. Blimbing	0.133	0.000	0.030
38. Lowokwaru	0.280	0.000	0.230
39. Batu	0.452	0.000	0.427
40. Junrejo	0.369	0.000	0.349
41. Bumiaji	0.538	0.000	0.514

The risk of decreasing wetland paddy productivity in Table 6.2 shows that in 2030, Greater Malang has a risk potential of decreasing wetland paddy productivity at low to high levels, except for Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, and Singosari. These regions have a very high risk potential of decreasing wetland paddy productivity, while Pujon, Klojen, and Blimbing have very low risk potential.

The risk result of decreasing dryland paddy productivity presented in Table 6.2 generally shows very low, low, moderate, and high levels of decreasing dryland paddy productivity, except for Sumbermanjing, Dampit, Wajak, and Singosari which have very high level of risk potential. The analysis result shows that most part of Greater Malang has very low and ow level of risk potential of decreasing dryland paddy productivity in 2030. Meanwhile, Greater Malang generally has very low to high levels of risk of decreasing corn productivity, except for Poncokusumo, Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Nganjum, Pakis, Jabung, and Singosari that have a very high level risk potential.

In summary, up to 2030 Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, Sumbermanjing, Dampit, Poncokusumo, Sumberpucung, Nganjum, Jabung, and Singosari have high or very high level of risk of decreasing productivity of wetland paddy, and corn. Therefore, attention should be paid on those seven sub-districts that need climate change adaptation strategy efforts. The objective is to maintain the production of the crops to deal with the threat of decreasing production of staple food crops in those regions. There are several adaptation strategies in facing the risk of decreasing food crops production due to climate change through technological improvements, such as crop cultivation and the use of superior seeds.

6.3 Risk of Decreasing Rainfed Harvested Area

The risk analysis result of decreasing harvested area of main food crops, namely paddy, and corn in Greater Malang is shown in Table 6.**3.**

Table 6.3 The Risk Analysis Result of Decreasing Rainfed Harvested Area of Staple Food Crops up to 2030 in Greater Malang

Sub-Districts	Level of Risk		
	Rainfed Paddy	Dryland Paddy	Corn
01. Donomulyo	0.569	0.247	0.161
02. Kalipare	0.557	0.607	0.463
03. Pagak	0.052	0.284	0.073
04. Bantur	0.460	0.292	0.263
05. Gedangan	0.242	0.073	0.270
06. Sumbermanjing	0.253	0.010	0.183
07. Dampit	1.000	1.000	0.564
08. Tirtoyudo	0.191	0.251	0.135
09. Ampelgading	0.117	0.000	0.032
10. Poncokusumo	0.174	0.000	0.273
11. Wajak	0.141	0.111	1.000
12. Turen	0.147	0.014	0.192
13. Bululawang	0.000	0.002	0.019
14. Gondanglegi	0.033	0.000	0.021
15. Pagelaran	0.059	0.000	0.045
16. Kepanjen	0.004	0.000	0.005
17. Sumberpucung	0.000	0.000	0.111
18. Kromengan	0.000	0.000	0.011
19. Ngajum	0.346	0.055	0.046
20. Wonosari	0.205	0.002	0.031
21. Wagir	0.064	0.041	0.157
22. Pakisaji	0.000	0.000	0.004
23. Tajinan	0.249	0.001	0.197
24. Tumpang	0.061	0.000	0.206
25. Pakis	0.037	0.000	0.043
26. Jabung	0.033	0.075	0.139
27. Lawang	0.172	0.000	0.095
28. Singosari	0.152	0.185	0.071
29. Karangploso	0.111	0.020	0.062
30. Dau	0.027	0.011	0.095
31. Pujon	0.008	0.000	0.046
32. Ngantang	0.177	0.000	0.135
33. Kasembon	0.206	0.006	0.105
34. Kedungkandang	0.000	0.000	0.020
35. Sukun	0.000	0.000	0.001
36. Klojen	0.000	0.000	0.000

Sub-Districts	Level of Risk		
	Rainfed Paddy	Dryland Paddy	Corn
37. Blimbing	0.000	0.000	0.000
38. Lowokwaru	0.000	0.000	0.001
39. Batu	0.001	0.000	0.048
40. Junrejo	0.001	0.000	0.023
41. Bumiaji	0.001	0.000	0.088

The risk analysis result of decreasing rainfed paddy **harvested area** that is presented in Table 6.**3** indicates that in 2030, the majority of district in Greater Malang have very low and low levels of risk of decreasing harvest area. Only Dampit that experiences very high level of risk of decreasing harvested area, while Donomulyo, Kalipare, and Bantur that experience moderate level of risk of decreasing harvested area of rainfed Paddy**.** Thus, it can be said that, only Dampit, Donomulyo, Kalipare, and Bantur that have the risk of decreasing rainfed paddy harvested area due to climate change. Those four districts require attention in order to adapt to climate change, for instance through enhancement of number of planting per year (i.e. planting index) and extensification of rainfed paddy crops.

Risk of reduction in harvested area of dryland paddy crops in 2030 shows that the majority of Greater Malang regions generally have risk of decrease in harvested area of dryland paddy at very low and low levels, except for Dampit Sub-Districts which have very high level and and Kalipare Sub-District which has high level.

Greater Malang experience risk of decreasing corn harvested area in 2030 at very low and low levels. Only Wajak that has very high risk level and Kalipare and Dampit that have moderate risk level.

Based on the risk analysis of decreasing harvested area of staple food crops in Greater Malang for 2030, it can be concluded that:

1) Dampit has very high risk of decreasing rainfed paddy harvested area.
2) Dampit and Kalipare have a very high and high risk of decreasing dryland paddy harvested area.
3) Wajak has very high risk of decreasing corn harvested area

The analysis result shows that Dampit, Kalipare, and Wajak have serious risk of decreasing harvested area of paddy and corn in 2030.

6.4 Risk of Decreasing Harvested Area of Irrigated Paddy Fields

The risk analysis results of decreasing harvested area of irrigated paddy in 2030 Greater Malang is shown in Table 6.4.

Table 6.4 Risk Analysis Result of Decreasing Irrigated Harvest Area of Irrigated Paddy in 2030 Greater Malang

Sub-Districts	Level of Risk
	Irrigated Paddy
01. Donomulyo	0.515
02. Kalipare	0.000
03. Pagak	0.000
04. Bantur	0.397
05. Gedangan	0.000
06. Sumbermanjing	0.229
07. Dampit	1.000
08. Tirtoyudo	0.198
09. Ampelgading	0.137
10. Poncokusumo	0.367
11. Wajak	0.252
12. Turen	0.747
13. Bululawang	0.306
14. Gondanglegi	0.275
15. Pagelaran	0.506
16. Kepanjen	0.923
17. Sumberpucung	0.487
18. Kromengan	0.542
19. Ngajum	0.471
20. Wonosari	0.125
21. Wagir	0.233
22. Pakisaji	0.499
23. Tajinan	0.411
24. Tumpang	0.389
25. Pakis	0.581
26. Jabung	0.603
27. Lawang	0.412
28. Singosari	0.874
29. Karangploso	0.673
30. Dau	0.062
31. Pujon	0.013
32. Ngantang	0.319
33. Kasembon	0.280
34. Kedungkandang	0.108
35. Sukun	0.094
36. Klojen	0.000
37. Blimbing	0.010
38. Lowokwaru	0.065
39. Batu	0.059
40. Junrejo	0.067
41. Bumiaji	0.134

The risk analysis result indicates that Greater Malang has a potential risk of decreasing irrigated Paddy harvested area at moderate, low, and very low levels. Only several sub-districts that experience risk of decreasing harvested area at high and very high levels, such as Dampit, Kepanjen, and Singosari (very high level) and Turen, Jabung, and Karangploso (high level).

Some parts of Greater Malang experience the climate change risk of decreasing harvested area of irrigated Paddy through increased evapotranspiration and rainfall variation.

Based on the risk analysis of decreasing harvested area of irrigated paddy up to 2030 in Greater Malang, it can be concluded that:

1. Dampit, Kepanjen, and Singosari have a very high risk of decreasing irrigated paddy harvested area
2. Turen, Jabung, and Karangploso have a high risk of decreasing irrigated paddy harvested area

6.5 Risk of Decreasing Food Crops Production

The risk analysis result of decreasing staple food crops of paddy and corn up to 2030 in Greater Malang is shown in Table 6.5. The risk maps of decreasing production of wetland and dryland paddy are shown in Figure 6.1 and Figure 6.2.

Table 6.5 Risk Analysis Result of Decreasing Production of Wetland Paddy, Dryland Paddy, and Corn up to 2030 in Greater Malang

Sub-Districts	Level of Risk		
	Wetland Paddy	Dryland Paddy	Corn
01. Donomulyo	0.437	0.245	0.118
02. Kalipare	0.339	0.492	0.348
03. Pagak	0.036	0.258	0.062
04. Bantur	0.357	0.341	0.232
05. Gedangan	0.158	0.144	0.236
06. Sumbermanjing	0.222	0.041	0.164
07. Dampit	0.919	1.000	0.492
08. Tirtoyudo	0.184	0.301	0.124
09. Ampelgading	0.121	0.000	0.031
10. Poncokusumo	0.295	0.006	0.303
11. Wajak	0.273	0.187	1.000
12. Turen	0.829	0.055	0.221
13. Bululawang	0.260	0.016	0.022
14. Gondanglegi	0.327	0.000	0.030
15. Pagelaran	0.614	0.000	0.053
16. Kepanjen	1.000	0.000	0.010
17. Sumberpucung	0.502	0.000	0.134
18. Kromengan	0.443	0.000	0.012
19. Ngajum	0.403	0.091	0.050
20. Wonosari	0.139	0.012	0.030
21. Wagir	0.191	0.067	0.132
22. Pakisaji	0.427	0.000	0.007
23. Tajinan	0.322	0.010	0.190
24. Tumpang	0.318	0.000	0.201
25. Pakis	0.584	0.000	0.055
26. Jabung	0.481	0.103	0.146
27. Lawang	0.393	0.000	0.093
28. Singosari	0.924	0.273	0.078
29. Karangploso	0.536	0.070	0.059
30. Dau	0.055	0.039	0.091
31. Pujon	0.010	0.000	0.047
32. Ngantang	0.248	0.000	0.132
33. Kasembon	0.210	0.022	0.098
34. Kedungkandang	0.100	0.000	0.016
35. Sukun	0.097	0.000	0.002
36. Klojen	0.000	0.000	0.000
37. Blimbing	0.010	0.000	0.000
38. Lowokwaru	0.059	0.000	0.002
39. Batu	0.052	0.000	0.040
40. Junrejo	0.057	0.000	0.020
41. Bumiaji	0.110	0.000	0.075

Most parts of Greater Malang generally experience potential risk of decreasing crop production at very low and low levels. Sub-districts that experience risk of decreasing production at moderate level are Donomulyo, Sumberpucung, Kromengan, Ngajum, Pakisaji, Pakis, Jabung, and Karangploso (irrigated paddy);

Kalipare and Singosari (dryland paddy); and Dampit (corn). Region that experience risk of decreasing production at high level is Pagelaran (wetland paddy). Meanwhile, regions which experience the risk of decreasing production at very high level are Dampit, Turen, Kepanjen, and Singosari (wetland paddy); Dampit (dryland paddy); and Wajak (corn).

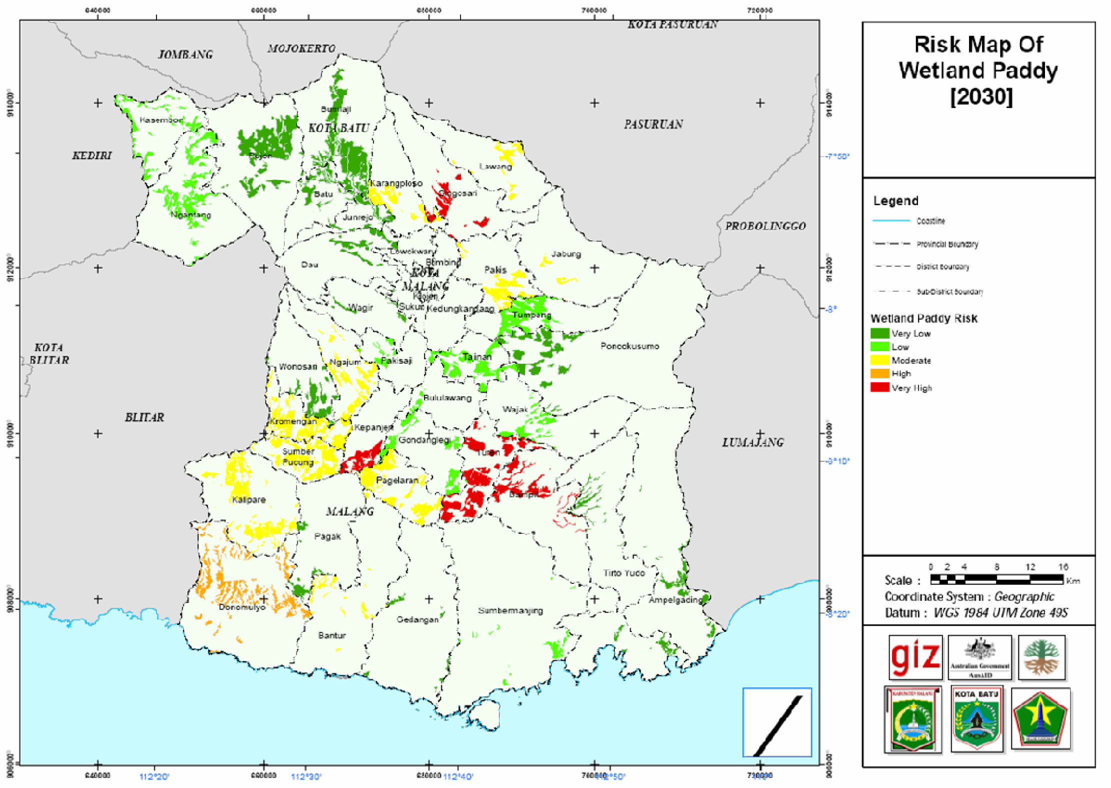


Figure 6.1 Risk Map of Decreasing Production of Irrigated Paddy up to 2030 in Greater Malang

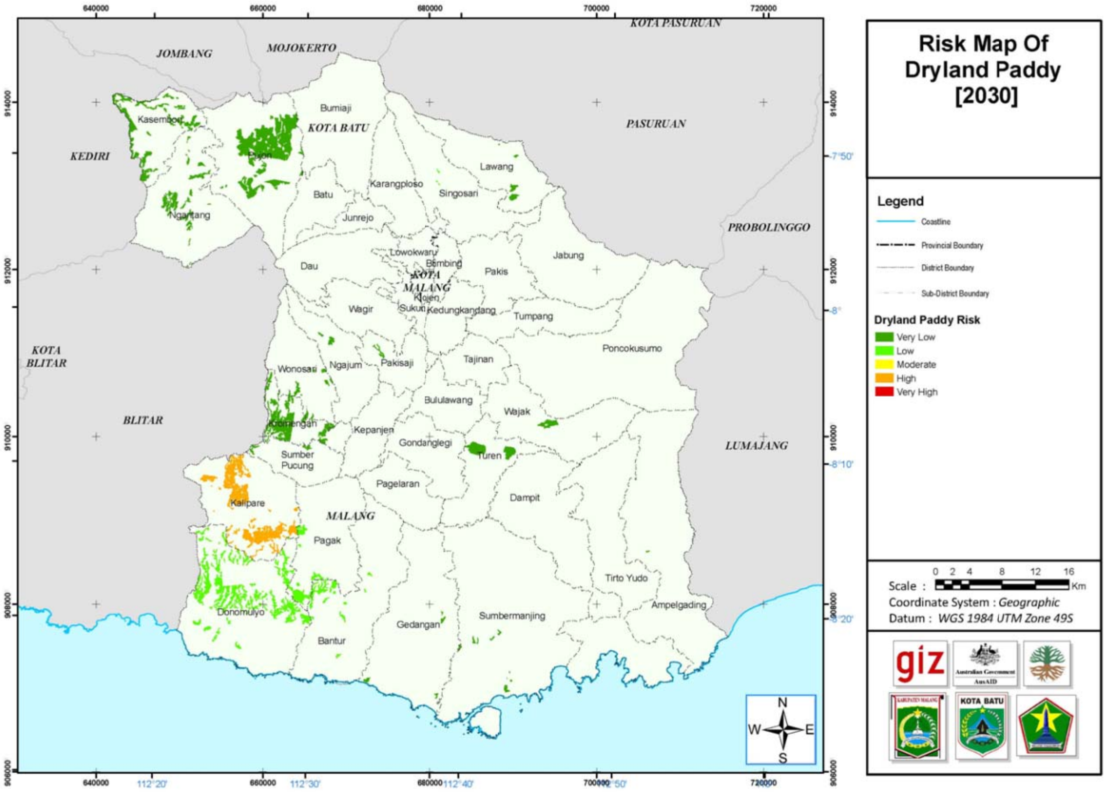


Figure 6.2 Risk Map of Decreasing Production of Dryland Paddy up to 2030 in Greater Malang

Based on the risk analysis of decreasing production of staple food crops up to 2030 in Greater Malang, it can be concluded that:

1) Dampit, Turen, Kepanjen, and Singosari have a very high risk of decreasing wetland paddy production.
2) Pagelaran has a high risk of decreasing wetland paddy production.
3) Dampit has a very high risk of decreasing dryland paddy production.
4) Wajak has a very high risk of decreasing corn production.

6.6 Summary of Risk of Decreasing Food Crops Production

The summary of risk analysis results of climate change on agriculture sector in 2030 Greater Malang are shown in Table 6.**6** to Table 6.**9.**

Table 6.6 The Distribution of risk of decreasing food crops productivity up to 2030 in Greater Malang.

Type of Crops	Sub-Districts		
	Moderate Risk	High Risk	Very High Risk
Wetland Paddy	Donomulyo, Kalipare, Pagak, Tirtoyudo, Ampelgading, Kromengan, Wonosari, Tajinan, Dau, Ngantang, Kasembon, Kedungkandang, Sukun, Batu, and Bumiaji	Bantur, Gedangan, Sumbermanjing, Dampit, Poncokusumo, Sumberpucung, Ngajum, Wagir, Pakisaji, Tumpang, Jabung, and Karangploso	Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, and Singosari
Rainfed Paddy	Donomulyo, Kalipare, Pagak, Wonosari, Tajinan, Dau, and Kasembon	Bantur, Gedangan, Tirtoyudo, Poncokusumo, Turen, Bululawang, Ngajum, Wagir, Pakisaji, Jabung, and Karangploso	Sumbermanjing, Dampit, Wajak, and Singosari
Corn	Donomulyo, Kalipare, Pagak, Kromengan, Wonosari, Kasembon, Kedungkandang, Batu, and Bumiaji	Bantur, Gedangan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Bululawang, Wagir, Pakisaji, Tajinan, Tumpang, Lawang, Karangploso, Dau,and Ngantang	Poncokusumo, Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Nganjum, Pakis, Jabung, and Singosari

Table 6.7 The distribution of risk of decreasing harvested area of rainfed fields up to 2030 in Greater Malang

Type of Crops	Sub-Districts		
	Moderate Risk	High Risk	Very High Risk
Rainfed Paddy	Donomulyo, Kalipare, and Bantur	-	Dampit
Dryland Paddy	-	Kalipare	Dampit
Corn	Kalipare and Dampit	-	Wajak

Table 6.8 The distribution of risk of decreasing harvested area of irrigated fields up to 2030 in Greater Malang

Type of Crops	Sub-Districts		
	Moderate Risk	High Risk	Very High Risk
Irrigated Paddy	Donomulyo, Pagelaran, Sumberpucung, Kromengan, Ngajum, Pakisaji, Tajinan, Pakis, and	Turen, Jabung, and Karangploso	Dampit, Kepanjen, and Singosari

	Lawang		

Table 6.9 The distribution of risk of decreasing food crops production up to 2030 in Greater Malang

Type of Crops	Sub-districts		
	Moderate Risk	High Risk	Very High Risk
Wetland Paddy	Donomulyo, Sumberpucung, Kromengan, Ngajum, Pakisaji, Pakis, Jabung, and Karangploso	Pagelaran	Dampit, Turen, Kepanjen, and Singosari
Dryland Paddy	Kalipare and Singosari	-	Dampit
Corn	Dampit	-	Wajak

Chapter VII Climate Change Adaptation Strategy For Agriculture Sector

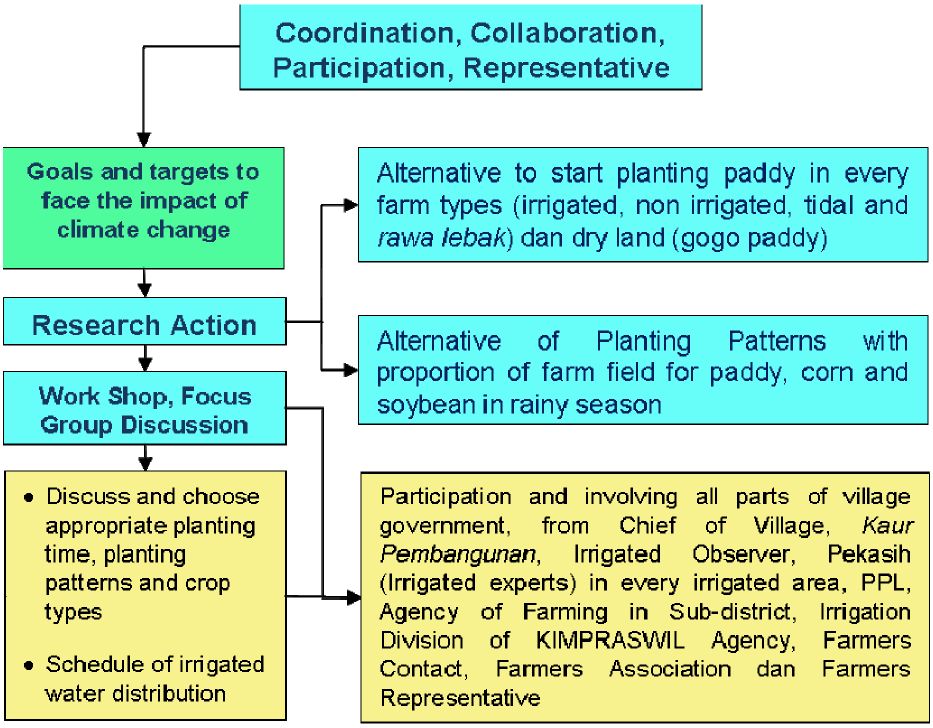
7.1 Climate Change Adaptation

Climate change impacts in agriculture sector of Greater Malang are indicated by air temperature and precipitation changes, among others.

Adaptation efforts are needed to prepare and anticipate the oncoming impacts. The adaptation efforts to various climate change impacts need different strategies, such as adaptation to air temperature rise, drought disaster, wet season shift, change of precipitation frequency and quantity, and also other extreme events.

In the climate change adaptation efforts of Greater Malang, we formulate 8 adaptation principals, which are (1) coordination, (2) collaboration, (3) participation/involvement accompanied by willingness, ability, and opportunity, (4) representative, (5) carrying capacity, (6) equity, (7) priority scale, and (8) sustainable natural resources of agriculture in the aspect of environment, social culture, and economy. To face the climate change in Greater Malang the strategy of adaptation, called the Grand Design Strategy, is formulated, as depicted in Figure 7.1.

Integrated adaptation is a function between related institutions and stake holders in adapting to climate change impact. School institutions as sources of experts should collaborate with *Dewan Nasional Perubahan Iklim* (National Climate Change Council), BMKG (Indonesian Agency for Meteorology, Climatology and Geophysics), local government agencies, such as BAPEDA (Environmental Impact Control Agency), *Badan Pengendalian Dampak Lingkungan Daerah* (BAPEDALDA; Local Environmental Impact Control Agency), and other related institutions. Likewise, local government's institutions should collaborate and coordinate with technical institutions in districts and sub-districts by involving other technical institutions such as P3A, PPL, *Kelompok Tani* (Farmers Groups), *Kontak Tani* (Farmers Contact), *Pekasih*, and farmers' representatives as participation effort to determine the adaptation strategy. Then, the principles can be integrated into a system in the form of the scheme in Figure 7.2.



Alternative to start planting paddy in every farm types (irrigated, non irrigated, tidal and *rawa lebak*) dan dry land (gogo paddy)

Alternative of Planting Patterns with proportion of farm field for paddy, corn and soybean in rainy season

- Discuss and choose appropriate planting time, planting patterns and crop types
- Schedule of irrigated water distribution

Participation and involving all parts of village government, from Chief of Village, *Kaur Pembangunan*, Irrigated Observer, Pekasih (Irrigated experts) in every irrigated area, PPL, Agency of Farming in Sub-district, Irrigation Division of KIMPRASWIL Agency, Farmers Contact, Farmers Association dan Farmers Representative

Figure 7.1 Grand Design Strategies to face the impact of climate change in Greater Malang

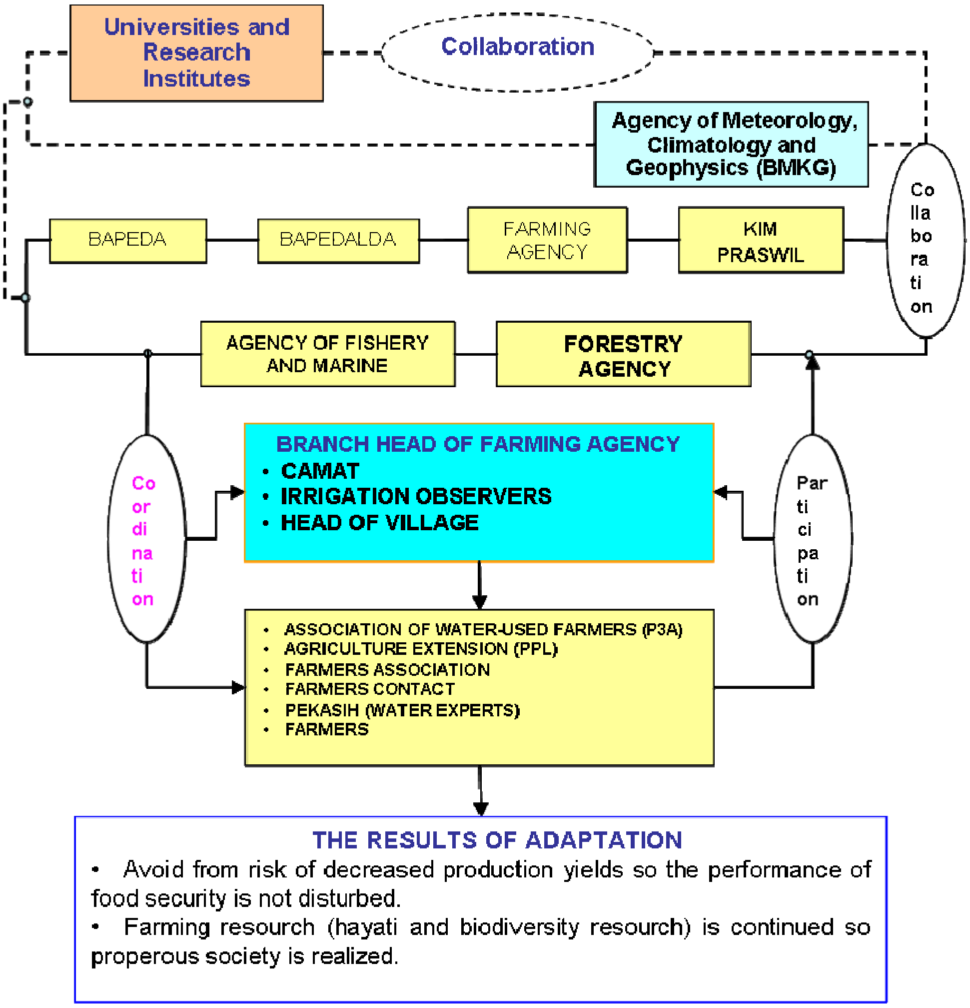


Figure 7.2 Value chain of integrated adaptation to the impact of climate change

7.2 Approach and Strategy Against Climate Change in Agriculture Sector

A simple example to overcome negative impact of climate change in the field is by planting albizia (*turi*), revitalization of irrigation networks, emergency reservoirs in rainfed areas, and the use of superior seeds with early ripening and high productivity. Meanwhile, the efforts to reduce poverty in villages are also adaptation activities, because societies or poor farmers are the most vulnerable to climate change impact due to minimum ability to adapt. All those activities need to be strengthened by obeying the principals of integrated enviromental management which includes analysis and assessment of climate change impact.

Increasing adaptation capability is not only focused on the efforts against change in enviromental biophysics, but also development of society's socio-economic endurance ability. Adaptation cannot be upheld if there is only ability with no strong willingness and awareness. It will be the same as dreams or brilliant plans with no action. Willingness and awareness will be well realized if supported by opportunity (chance). Thus, regulations and policies are needed, which must be obeyed and understood by various societies.

There are several adaptation strategy efforts against the risk of decreasing crop production due to climate change in Greater Malang; they are:

1. Increasing crop productivity through superior variety/seed, cultivation technology, fertilizer, and equipments.
2. Increasing agricultural field areas to increase crop areas and harvested areas through field reclamation, field optimization, and new fields.
3. Food diversification through planting of potential crops which can adapt to climate change, such as early ripening crops, drought resistant crops, and inundation resistant crops.
4. Revitalization of planting pattern according to changes of distribution and frequency of precipitation.
5. Limit land conversion from agriculture to non-agriculture using laws.
6. Coordination between related institutions with agricultural activities in the climate change adaptation strategy.

7.2.1 Adaptation Strategy of Decreasing Crop Productivity

The result of risk analysis of decreasing food crop productivity due to climate change shows that there are several very high risk sub-districts; they are Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, Sumbermanjing, Dampit, Poncokusumo, Wajak, Sumberpucung, Nganjum, Jabung, and Singosari (Figure 7.1). Those districts are generally dominated by rainfed fields which experience temperature increase and high precipitation variability. Furthermore, the districts do not have sufficient irrigation network, causing high potential of drought (crops experience water deficit) and decreasing crop productivity. The distribution of risk of decreasing crop productivity in Greater Malang for 2030 is shown in Figure 7.1.

Table 7.1 Areas with high risk in decreasing productivity of major food crops in Greater Malang.

Type of Crops	Sub-District	
	High Risk	Very High Risk
Wetland Paddy	Bantur, Gedangan, Sumbermanjing, Dampit, Poncokusumo, Sumberpucung, Ngajum, Wagir, Pakisaji, Tumpang, Jabung, and Karangploso	Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, and Singosari
Dryland Paddy	Bantur, Gedangan, Tirtoyudo, Poncokusumo, Turen, Bululawang, Ngajum, Wagir, Pakisaji, Jabung, and Karangploso	Sumbermanjing, Dampit, Wajak, and Singosari
Corn	Bantur, Gedangan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Bululawang, Wagir, Pakisaji, Tajinan, Tumpang, Lawang, Karangploso, Dau,and Ngantang	Poncokusumo, Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Nganjum, Pakis, Jabung, and Singosari

High risk areas are caused by high hazard due to increased temperature and precipitation variability, and other factors of high vulnerability to climate change with high exposure and sensitivity, while having low adaptive capacity.

Previously, Greater Malang farmers had cultivated their rainfed paddy field by applying *rancah* system (wet field paddy). Farmers began to plant paddy right after the onset of wet season by sowing seeds because these rainfed fields' source of water only came from rainfall. Paddy planting with this system is prone to hazard of decreasing productivity due to long dry season. Then, starting 1980, this paddy production technology was shifted to *gogorancah* system (GORA) which is a combination of two paddy planting systems, *gogo* system (rice cultivation in the dryland (rainfed field) without water-logging in the rice crop) and *rancah* system (rice cultivation in wetland (irrigated field) with water-logging in the rice crop).

Drought disasters occurred in Greater Malang in 2003 and then in June, July, and Auguts of 2009, hundreds of hectare of rainfed fields experienced decreasing productivity, causing drops of rice supply. These disasters indicate that climate change has shown its impact to agriculture in Greater Malang, meaning that agriculture sector is vulnerable to climate change.

There are some alternative adaptation strategies to anticipate the risk of crop productivity:

1. Use superior seeds with high productivity, early ripening, and resistance to drough or flood.

Strategy: Ensure that main crop productivity could be sustained using superior variety.

Program : development of various main crop varieties with superior productivity, early ripening, and resistance to drought or flood

- Activity 1 : campaigning the benefit of using superior paddy varieties with early ripening and resistance to drough or flood as an effort of climate change adaptation.
- Activity 2 : Find or engineer early ripening paddy variety through cooperation with *Balai Besar Penelitian Padi-Padian* (Rice Research Institute) and *Pemulia Tanaman* (Crop Breeders) to find superior varieties with early ripening and resistance to drought or flood.

Strategy: Ensure that main crop productivity could be sustained or increased by increasing cultivation technology and crop intensification.

a) Program 1 : Development of cultivation technique such as integrated crop management and cultivation intensification of *System of Rice Intensification* (SRI).

- Activity 1 : Socialize cultivation technique of integrated crops management system for paddy (rice) and corn
- Activity 3 : Create rainfed reservoirs by making channels with one meter depth and 50 cm wide around the fields and/or in the middle of the field to ensure the use of SRI system.

- Activity 4 : Develop paddy cultivation of *legowo* system to increase the bordereffect, increasing productivity.
- Activity 5 : Development of paddy planting with *Gogorancah Tanpa Olah Tanah* (TOT; *Gogorancah* Without Soil Cultivation) system in rainfed areas. Gogorancah is the main system of paddy planting efforts in rainfed areas, as done in South Lombok. The TOT has agronomical and economical advantages due to easier change to mud if inundated by water. Paddy crop needs muddy soil, making mud production irrelative.

a) Program 2 : Strengthening main crops farming efforts through optimization of fertilizer according to crops' soil need.

- Activity 1 : Disseminating and campaigning fertilizer for paddy and corn, efficiently and effectively.

Activity 2 : Socialize environmental friendly organic fertilizer which could repair the physical, chemistry, and biological characteristics to support sustainable agriculture with high crop productivity.

7.2.2 Adaptation Strategy of Decreasing Harvested Area

The analysis result of decreasing main crop harvested area due to climate change shows that there are several high and very high risk regions; they are Sub-District of Dampit for wet paddy field; Sub-District of Kalipare for dry paddy field; and Sub-Districts of Wajak for corn field (Table 7.2). Regions with high risk of decreasing harvested area are generally dominated by rainfed fields and also experience increasing temperature and decreasing precipitation. Furthermore, the regions do not have sufficient irrigation network, increasing high potential of drought and decreasing harvested area. The distribution of regions (sub-districts) with risk of decreasing harvested area in Greater Malang for 2030 is shown in Table 7.2.

Table 7.2 Subdistricts with high risk in decreasing harvested areas of major food crops in rainfed land

Type of Crops	Sub-District

	Moderate Risk	High Risk	Very High Risk
Rainfed Paddy	Donomulyo, Kalipare, and Bantur	-	Dampit
Dryland Paddy	-	Kalipare	Dampit
Corn	Kalipare and Dampit	-	Wajak

High risk regions of decreasing harvested area are due to temperature rise and decreasing precipitation and other factors of high vulnerability to climate change with high exposure and sensitivity and low adaptive capacity.

Alternative adaptation strategies for regions with risk of decreasing harvested area caused by drought are :

1. Increasing rain water reservoir capacity during wet season.

Strategy: Ensure water availability in the field to irrigate crops when there is no rainfall.

a) Program 1: Increase water availability by utilizing rain water.

- Activity 1: Facilitate and encourage farmers to create waterponds in the field for water harvesting, considering the relatively short wet season.

Reservoirs creation to increase rainfed capacity is conducted in regions vulnerable to drought such as Donomulyo, Pagak, Turen, and Kalipare sub-districts. The risk analysis result of decreasing harvest area shows that the districts are very vulnerable to drought due to uneven rain distribution and relatively short wet season. However, in certain months along November to mid-February, relatively high frequency and intensity of rainfall might occur, impacting the decreasing quality and quantity of paddy harvest.

- Activity 2: Facilitate farmers to do site visit to regions which have implemented rain harvesting using reservoirs. Site visit is to directly show the rain harvesting model using reservoirs.

2. Revitalization of irrigation network

Strategy: Ensure water supply for crops using irrigation network to handle the decreasing harvested area in the attempt of climate change adaptation.

a) Program 1 : Encourage *Dinas Pengairan* (PU; Water Service of Public Works) to develop new irrigation network in regions with wide area of harvest
   - Activity 1 : Assist and cooperate in identifying potential agricultural fields to develop its irrigation network.
   - Activity 2 : Socialize the use and maintenance of irrigation network by involving farming society as the user of irrigation network.

b) Program 2 : Increasing the capacity of society's existing reservoirs.
   - Activity 1 : Help and facilitate farmers which already own reservoirs to renovate those experiencing sedimentation.

Basically, climate change impact in Greater Malang's rainfed regions has been anticipated by farmers, individually and group. Many reservoirs experience shallowing (sedimentation). To increase the capacity of water reservoirs, those experiencing sedimentation need to be renovated by facilitating farmers financially or using equipments.

   - Activity 2 : Motivate farmers through workshops on the need of rain harvesting by using reservoirs around the fields.

3. Utilization of superior early ripening paddy, corn, and soybean.

Strategy: Preventing harvest failure caused by low precipitation and short wet season in rainfed areas.

a) Program 1 : Ensure main crops harvest by increasing farmers understanding on the benefit of early ripening varieties as efforts of climate change adaptation in rainfed areas.
   - Activity 1 : Motivate seed breeders to produce superior and early ripening paddy seeds.
   - Activity 2 : Give helps to farmers by subsidizing early ripening crop seeds.

b) Program 2 : Socializing and campaigning the utilization of various early ripening superior variety of paddy and corn for climate change adaptation.

- Activity 1 : Provide information and ensure farmers on the utilization of planting superior varieties of early ripening paddy and corn related to the risk of decreasing harvested area caused by climate change.

From the *Green Revolution* until recently, farmers have been confronted with various options of paddy varieties with a growing period of 105 – 115 days. Farmers have various options and preferences to plant paddy varieties, such as Ciherang, Ciguilis, Cibogo, Mikongga, Widas, Cilosari, Citubagendit, Citara, Pelita, IR 64, *etc.* Considering the duration of wet season in Greater Malang from November to February (around 4 months), then the utilization of superior early ripening variety, that is 85-90 days, is very recommended.

- Activity 2 : Development of seed technology to find varieties of paddy and corn which are early ripening and resistant to drought. This activity is conducted by coordination and collaboration between schools, agricultural research and development institutions, and *Dinas Pertanian* (Agriculture Service).

7.2.3 Adaptation Strategy of Decreasing Harvested Area of Irrigated Fields

The analysis result on risk of decreasing harvested area of irrigated fields shows that several regions have high and very high risk of decreasing harvested area of irrigated fields; they are sub-district of Dampit, Kepanjen, and Singosari for wet paddy field (Table 7.3). Those regions generally have wide areas of irrigated fields and experience temperature rise and decreasing precipitation. Although having irrigation network, climate change potentially causes drought that may decrease harvested area. The distribution of regions with the risk of decreasing harvested area of irrigated fields on Greater Malang in 2030 is shown in Table 7.3.

Table 7.3 Districts with high risk of decreasing harvested areas of irrigated paddy.

Type of Crops	Sub-District		
	Moderate Risk	High Risk	Very High Risk
Irrigation	Donomulyo,	Turen, Jabung, and	Dampit, Kepanjen, and

Paddy	Pagelaran, Sumberpucung, Kromengan, Ngajum, Pakisaji, Tajinan, Pakis, and Lawang	Karangploso	Singosari

High risk of decreasing harvested area of irrigated fields are not so different with those of rainfed fields caused by increasing temperature and decreasing precipitation and other factors of vulnerability to climate change with high exposure and sensitivity and low adaptive capacity.

There are several alternative adaptation strategies for this kind of risk. The strategies, programs and activities are similar to those described previously in 7.2.2 which include (1) Increasing capacity of rainfed reservoirs on wet season, and (2) Revitalization of irrigation network.

7.2.4 Adaptation Strategy of Decreasing Crop Production

The analysis result of decreasing main crops harvested area due to climate change shows that there are several high and very high risk regions. The distribution of regions with risk of decreasing harvested area in 2030 Greater Malang is shown in Table 7.4.

Table 7.4 Subdistricts with high risk of decreasing production of major food crops in Greater Malang.

Type of Crops	Sub-District		
	Moderate Risk	High Risk	Very High Risk
Wetland Paddy	Donomulyo, Sumberpucung, Kromengan, Ngajum, Pakisaji, Pakis, Jabung, and Karangploso	Pagelaran	Dampit, Turen, Kepanjen, and Singosari
Dryland Paddy	Kalipare and Singosari	-	Dampit
Corn	Dampit	-	Wajak

Since production is the product of productivity (yield) and harvested area, thus, the strategy to suppress the decline of crop production is by taking into account both adaptation for productivity and harvested area as been previously described. Other strategies include the following.

1. Development of Raised Bed Farming System for soil and water conservation of rainfed fields.

Strategy: Preventing farmers' profit loss due to harvest failure by shifting production technology to raised bed farming system.

a) Program 1 : Increasing productivity of rainfed field and farmers' income by raised bed farming system as management effort of field and crop on rainfed fields.

    - Activity 1 : Facilitate farmers to do field and crops management by implementing raised bed farming system.

Raised bed farming system is not new to farmers in places such as Lombok, but to Greater Malang farmers. Implementing raised bed farming system provides an opportunity to farmers to conduct diversification of crops and choose non-paddy commodies with high economic value. As such, farmers have higher income through increasing quality and quantity output who do not only focus on comparative advantage, but also competitive advantage by making a proportion of paddy fields on wet season for non-paddy crops with high economic value.

- Activity 2 : Introduce ACM and facilitate farmers to try to implement ACM on rainfed fields.

ACM is a farming effort system on rainfed fields by dividing fields with a proportion of 1/3 from its planting area for planting non-paddy crops with high economic value (various vegetables or seasonal fruits) by implementing "Permanent Raised Bed Farming System". Meanwhile, the 2/3 rest of it can be planted with the GORA (Gogo Rancah) system paddy on wet season with *rancah* system (wet field paddy) with no raised bed (*flat*). Then, on the Dry Season 1 and Dry Season 2, planted with non-paddy crops (vegetables and or seasonal fruits).

2. Optimization of rainfed fields using pumping irrigation water, *tata air mikro* (TAM; micro water order), *jaringan irigasi tingkat tani* (JITUT; farmer level

irrigation network), *jaringan irigasi desa* (JIDES; village irrigation network), reservoirs, and reforestation.

Strategy: Increase the utilization of rainfed fields capacity using pumping on rainfed regions of the Sub-districts of Greater Malang such as in Dampit, Turen, Kepanjen, Pagelaran, and Singosari.

.

a) Program 1 : Optimize the utilization of rainfed fields by legalize pumping irrigation water from irrigation channels.

In Donomulyo, Kalipare, Bantur, Dampit, Ngajum, Wonosari, and Tajinan there are rainfed fields vulnerable to climate change impact, although there are irrigation channels in the area. The water cannot be directly accessed for irrigating fields through secondary, tertiery, or even quarterly channels due to the higher position of irrigation channels.

- Activity 1 : Facilitate farmers to create water reservoirs inside the fields to collect water pumped from irrigation channels.
- Activity 2 : Facilitate farmers to legalize collection of irrigation water from rivers/irrigation channels using pumping machines.

Thus, the activity of legal pumping development in the regions needs to be done through coordination with *Dinas Pengairan and Dinas Pertanian Sub-District and Kecamatan* of *Dinas Pekerjaan Umum* (PU; District and Sub-District Water Service and Agriculture Service of Public Works).

b) Program 1 : Optimize the utilization of rainfed fields by developing *tata air mikro* (TAM).

- Activity 1 : Facilitate farmers to create TAM on their fields for irrigating their fields.
- Activity 2 : Develop TAM system on its fields for irrigating their fields

c) Program 1 : Optimize the utilization of rainfed fields by developing JITUT.

- Activity 1 : Facilitate farmers to create JITUT on their fields for irrigating their fields.

- Kegiatan 2 : Develop JITUT system on their fields for irrigating their fields

d) Program 1 : Optimize the utilization of rainfed fields by developing *jaringan irigasi desa* (JIDES).

This program could be applied in Ngajum, Wonosari, and Tajinan where there are rainfed fields vulnerable to climate change impact.

- Activity 1 : Facilitate farmers to create JIDES on their fields for irrigating their fields.
- Activity 2 : Develop JIDES system on their fields for irrigating their fields

e) Program 1 : Optimize the utilization of rainfed fields by creating reservoirs.

- Activity 1 : Facilitate farmers to create reservoirs on their fields to irrigate their fields.
- Activity 2 : Develop reservoirs system on their fields for irrigating their fields

f) Program 2 : Widely encourage the planting of albizia (*turi*) on field's bunds and other nitrogen rich crops. Albizia, other than as feed for livestock, can also be utilized as green fertilizer.

- Activity 1 : Stocking albizia seeds by *Dinas Pertanian* to be given to farmers on rainfed field
- Activity 2 : Campaigning albizia planting on rainfed fields.

7.3 Summary Adaptation Strategy to Climate Change Impacts of Agricultural Sector

Summary of adaptation strategy to producivity, harvested area, and production decrease of main crop in Greater Malang is shown in Table 7.**5**.

Table 7.5 Summary of adaptation strategy to climate change impact of agriculture sector in Greater Malang

Hazard (H)	Vulnerability (V)	Risk (R)	Priority Districts	Adaptation Strategy
Decreasing Crops Productivity	Vulnerable	High	• Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, and Singosari (wetland Paddy) • Sumbermanjing, Dampit, Wajak, and Singosari (dryland Paddy) • Poncokusumo, Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Nganjum, Pakis, Jabung, and Singosari (Corn)	1. Using superior seeds with high productivity, short life, and resistance to drought or floods. 2. Increasing the technique of agricultural cultivation, such as through PTT and cultivational intensification (SRI and *Legowo* system)
Decreasing Harvested Area of Rainfed Field	Vulnerable	High	• Dampit, Turen, Kepanjen, Singosari, and Pagelaran (wetland paddy) • Kapipare and Dampit (dryland paddy) • Wajak (Corn)	1. Increasing capacity of rain water reservoirs on wet season 2. Revitalization of irrigation network 3. Use of superior seeds of paddy, corn, and soybean seeds with higher quality and early ripening.
Decreasing Harvested Area of Irrigated Field	Vulnerable	High	• Dampit, Kepanjen, Singosari, Turen, Jabung, and Karangploso (wetland paddy)	1. Increasing capacity of rain water reservoirs on wet season. 2. Revitalization of irrigation network and tides sluice gates 3. Conservation of soil and water on agricultural field.
Decreasing Crop Production	Vulnerable	High	• Dampit, Turen, Kepanjen, Singosari, and Pagelaran (Wetland paddy) • Dampit (Dryland paddy) • Wajak (Corn) • OKU Timur (soybean)	1. Use of superior seeds of paddy, corn, and soybean seeds with higher quality and early ripening. 2. Increasing the technique of agricultural cultivation, such as through PTT and cultivational intensification (SRI and *Legowo* system) 3. Development of raised bed cultivation system to conserve land soil and water on rainfed fields..

Hazard (H)	Vulnerability (V)	Risk (R)	Priority Districts	Adaptation Strategy
				4. Optimization of utilization of rainfed fields by reforestation. 5. Optimization of utilization of abandoned land reclamation, and opening of new fields.

Chapter VIII Conclusions and Recommendations

Based on the analysis results of hazard, vulnerability, and risk of climate change on agriculture sector in Greater Malang, several conclusions and recommendations can be proposed.

8.1 Conclusions

a. Based on the analysis of air temperature and rainfall in Greater Malang, there are indications of climate change. The air temperature increases between 0.7^{o}C to 0.8^{o}C and rainfall has been more fluctuative since 1981. The impacts of climate change in Greater Malang have been identified by the community which is indicated by the shifting of growing season and harvesting time of paddy and corn. This change is also indicated by the change of hythergraph and climate types (Oldeman classification) in Greater Malang.

b. The agriculture sector in Greater Malang is vulnerable to the impacts of climate change, indicated by hazards such as decreasing productivity, harvested area, and production of paddy and corn due to air temperature increase and rainfall change.

c. Areas experiencing high exposure to climate change in Greater Malang are Dampit, Turen, Kepanjen, Singosari, and Wajak Sub-districts (very high exposure level), and also Pagelaran and Sumberpucung Sub-districts (high exposure level).

d. Based on the results of climate change hazard analysis on agriculture in Greater Malang, areas susceptible to decreasing productivity of staple food crops are Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Pakis, Lawang, Singosari, sukun, and Blimbing Sub-Districts (wetland paddy); Bantur, Gedangan, Dampit, Tirtoyudo, Wajak, and Singosari Sub-District (dryland paddy); and Poncokusumo, Wajak, Turen, Gondanglegi, Pagelaran, Kepanjen, Sumberpucung, Tumpang, Pakis, Jabung, Singosari, Pujon, and Ngantang Sub-District (corn). Areas susceptible to the decreasing harvested area are Dampit, Kepanjen, Singosari, Donomulyo, Kalipare, Turen, Jabung, Sumberpucung, Kromengan, and Karangploso Sub-Districts (wetland paddy); Kalipare and Dampit Sub-Districts (dryland paddy); and Wajak Sub-Districts (corn). According to the decreasing productivity, harvested area, or both, that cause declining food crop production are Dampit, Turen, Kepanjen, Singosari, Pagelaran, and Sumberpucung Sub-District (wetland paddy); Dampit (dryland paddy); and Wajak Sub-District (corn).

e. Based on the analysis of vulnerability to climate change in Greater Malang, the most vulnerable areas are Donomulyo, Bantur, Gedangan, Sumbermanjing, Dampit, Tirtoyudo, Ampelgading, Poncokusumo, Wajak, Turen, Bululawang, Gondanglegi, Pagelaran, Kepanjen, Ngajum, Wagir, Pakisaji, Tajinan, Tumpang, Pakis, Jabung, Lawang, Singosari, Karangploso, Dau, and Ngantang Sub-Districts. Those areas generally experience high exposure and sensitivity but low adaptive capacity to climate change.

f. Areas with risk of decreasing production of staple food crops in Greater Malang are Dampit, Turen, Kepanjen, Singosari, and Pagelaran Sub-District (wetland paddy); Dampit Sub-District (dryland paddy); and Wajak Sub-District (corn). Those areas experience high hazard of decreasing productivity and harvested area due to climate change. Generally, Greater Malang experiences large decrease in food crop productivity with an average of 0.62% (wetland paddy), 0.53% (dryland paddy), and 0.50% (corn) per year. The average decreases in crop production are 0.59%, 1.59%, and 0.58% per year, respectively, for wetland paddy, dryland paddy, and corn. Future consequences include declining surplus of food crops, especially paddy production in Greater Malang.

g. Although climate change has caused negative impacts to food crop production, but decreasing apple production of Batu city was the result of confounding factors particularly of climate variables and its production inputs. Indeed, the available limited data cannot distinguish the impacts between the two and, hence, this study cannot portray the impact of climate change on apple production over a wide range of temperature and rainfall. Decreasing apple production in Malang Raya is more caused by socio-economic aspects related to price of agricultural inputs and the crop yield. The remaining apple production areas are in the sub-districts of Bumiaji, Sidomulyo and Punten. Detailed descriptions are presented in the appendix below.

8.2 Policy Recommendations

a) Increase the technology of paddy, corn, and soybean cultivation, for example through integrated crop management (ICM) program and System of Rice Intensification (SRI) to overcome the risk of decreasing productivity of staple food crops due to climate change.

b) Increase the use of varieties with high productivity and resistance to drought or floods, as well as short-duration cultivars to increase the productivity of staple food crops.

c) Increase the use of intensification, reclamation, and optimization of agricultural areas (bare lands) or opening new lands to maintain or increase the harvested area of agricultural crops in Greater Malang.

d) Strengthen the implementation of adaptation program in Greater Malang through the arrangement of Grand Design Strategy by considering the elements of integrated environmental management principles, namely (1) Coordination, (2) Collaboration, (3) Participation/Involvement (willingness, ability, chance or opportunity), (4) Representation, (5) Carrying capacity, (6) Equity, (7) Priority Scale, and (8) Sustainability of agriculture’s natural resources in the environmental, socio-cultural and economic aspects. Adaptation is not only focused on efforts to cope with changes in biophysical environment, but also includes increasing institutional capacity and resilience of socio-economic development of poor people to strengthen the ability to survive (resilience) and reducing the vulnerability level. Therefore, it is necessary to strengthen farmers’ community capacity by empowering and facilitating the creation of irrigation system, making ponds to gather water during rainy season in rainfed areas, and facilitating the renovation of irrigation system and ponds which experience siltation (sedimentation).

e) Take advantage of climate prediction and climate forecasting for the beginning of planting season. BMKG should collaborate~~d~~ with the Ministry of Agriculture to coordinate the observer and conduct regular recording of rainfall and other climatic elements in every station.

f) Develop a Climate Field Schools (SLI) in Greater Malang by adopting the success of Integrated Pest Management Field School (SLPHT).

g) Conduct integrated and multi-location studies on the changes of planting schedule and planting patterns in every irrigated or non-irrigated area for each region through collaboration and involvement of research institutions and universities. The results of this study are used as the basis for coordinating the beginning of planting schedule for every planting season and adjusting the cropping patterns which are more adaptive to climate change to prevent the hazard of decreasing quality and quantity of production.

h) Facilitate and encourage farmers in the wetland areas, which are vulnerable to the impacts of climate change, to diversify crops in the rainy season by dividing the proportion of paddy fields for paddy and vegetable crops and/or crops with high economic value.

i) Regularly provide information about the capacity and discharge of river water as the source of irrigation water to the Ministry of Agriculture. There should also be available information about rainfall from the BMKG by installing more rainfall stations

j) Process agricultural wastes into organic fertilizer and prevent burning of straws. Generating effort to utilize agricultural waste into organic fertilizer is one of the adaptation strategies that require technological innovation.

k) Develop irrigation channels to expand planting areas by adding the range of irrigation water distribution. Drainage channel development is also necessary to overcome the hazard of floods in areas that are potentially exposed to hazard during harvest period due to the high frequency and intensity of rainfall.

l) Encourage farmers to create small ponds at farmers' paddy fields to collect rain water (rain harvesting), considering the relatively short rainy season. The construction of ponds to increase the storage capacity of rain water is conducted in areas vulnerable to drought such as Donomulyo, Pagak, Turen, and Kalipare Sub-Districts.

m) Help poor farmers in improving the adaptation capacity by strengthening rural economy.

n) Campaigning paddy cultivations with Zerro Tillage (TOT) *Gogorancah* system in rainfed paddy fields and water-saving cultivation paddy system, known as SRI (System of Rice Intensification) that have been tested in areas that are vulnerable to the deficit of irrigation water. The development of paddy cultivation in this system should be accompanied with the experiment on invention of drought-resistant and early-ripening varieties.

o) Promote widely the planting of albizia or agati in rainfed paddy field areas for land conservation, because albizia plants are beneficial for animal feed and useful for green manure.

p) Create policies of food diversification program, to reduce the consumption of rice and planting programs of other potential food crops that can adapt to climate change, such as short-aged plants, drought tolerant, or flood resistant.

q) Create policies that suppress the conversion of agricultural land into non-agricultural land to sustain fertile agricultural land.

r) Strengthen inter-agency coordination related to agricultural activities in the implementation of adaptation strategy to climate change.

s) Some recommendations to maintain apple production are to rehabilitate apple plantation by changing old apple crop with the young ones; to prevent the conversion of apple plantation areas to the non apple ones and to provide incentives for apple farmers so that they would still have passion to plant apple and would not change their occupations.

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Appendix: Impacts of Climate Change on Batu Apple Production

A.1. Apple Growth and Impacts of Climate

Apple (*Malus sylvestris* Mill) is an annual fruit crop that was originated from West Asia region which has sub-tropical climate. In Indonesia, apple has been planted since 1934 until today. It grows and yields fruits in upland areas, which have relatively low temperature. Up to now, only few regions develop apple plantations. Malang region in the East Java Province is one of these regions that develop apple plantations in large areas, where Its production centers are located in Batu City and Poncokusumo sub-district of Malang District. In these areas, the initial production of plantations was between 1960 which then increased substantially till now. Besides, apple plantations are also developed in other provinces such as East Java (Kayumas-Situbondo, Banyuwangi, Nongkojajar-Pasuruan), Central Java (Tawangmangu-Karanganyar), Bali (Buleleng and Tabanan), West Nusa Tenggara, East Nusa Tenggara, and South Sulawesi.

Apple entered Indonesia during Dutch colonialism era. However, it has been planted for commercial purpose since 1960s after people found the deciduous system artificially or manually. There are several apple varieties planted in Indonesia that have unique characteristics. The superior apple varieties are: Rome Beauty, Manalagi, Anna, Princess Noble and Wangli or Lalijiwo.

Apple plantations need environment with characteristics of particular low temperature, low humidity and sufficient rainfall. Some requirements of apple crop growth are:

1) Ideal rainfall is 1,000-2,600 mm/year with rainy days are about 110-150 days/year. In a year, the wet and dry months should be 6-7 months and 3-4 months, respectively. High rainfall in the flowering season will cause the flowers fall so that prohibits fruit development.

2) Apple crop need sufficient of sun light around 50-60% everyday especially in flowering season.
3) Appropriate temperature is around 16-27°C.
4) Required air humidity is around 75-85%
5) Suitable altitudes are about 700-1200 m with optimal value of around 1000-1200 m above mean sea-level.

Batu City has a highland agro-climate characteristic with dry climate so that this agro-tourism city is suitable as the center of apple production in Indonesia. The farm potential of apple is shown by the high social economy and the welfare of apple businessman especially in 1980 until the middle of 1990s. The development of apple production has been supported by the development of other businesses such as agro-input suppliers, transportation service, and home industry which become an attraction for the development of agro tourism industry in Batu City. The varieties of apple from Batu City that have been adapted and known in market today are Rome Beauty, Manalagi and Anna.

Apples farm was initially produced in the yard then it continues to the large field which is planted with vegetables. The fields are now intensively maintained. The number of apple crop reached 1,974,366 trees with the production of 842,799 quintal (BPS and Bapeda Batu city, 2010). The increasing agribusiness activity of apple commodity may be constraint by climate change. The efforts should be made to overcome this problem for the benefit of apple farmers. However, the available data is very limited to analyze the hazard of climate change on apple production for which apple plantation is separately discussed from the food crops (rice and maize) in Malang Raya.

A.2. Apple Production and its Relation to Climate

Apple production in Batu City has changed over time. It can be seen from Table A.1 and Figures 1 to 4 based on those limited data, it is difficult to draw a conclusion on the effect of climatic variability and hence climate change on apple production.

Table A.1 Data of Apple production, Temperature and Rainfall of Batu City

Year	Sum of Apple Tree	Production (tons)	Productivity (kg/ tree)	Temperature (^{O}C)	Rainfall (mm)
1999	1,802,717	46,189	19.6	21.4	2171
2000	2,874,753	52,243	37.3	21.4	2007
2001	3,452,010	45,027	13.4	21.5	1924
2002	1,471,760	17,249	10.9	21.9	1878
2003	1,539,842	27,293	14.6	22.0	1838
2004	1,707,052	67,431	45.9	21.9	2081
2005	4,685,468	1,62,832	38.4	22.2	1897
2006	4,091,321	2,09,751	42.7	22.1	1643
2007	4,035,058	61,100	14.0	21.3	2101
2008	4,349,203	1,23,008	28.8	21.8	1912
2009	3,608,375	1,69,074	58.6	22.0	1726
2010	1,974,366	84,279	17.0	22.3	3344

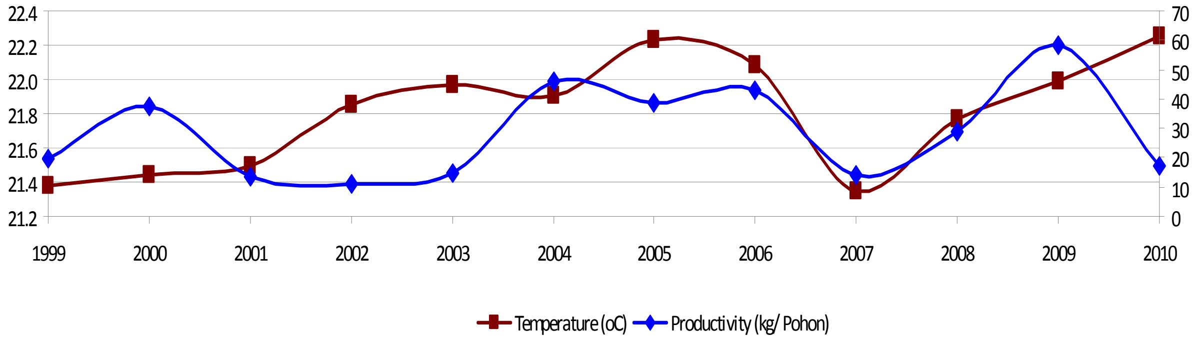

Figure A.1 Apple Productivity and Air Temperature of Batu City over Time

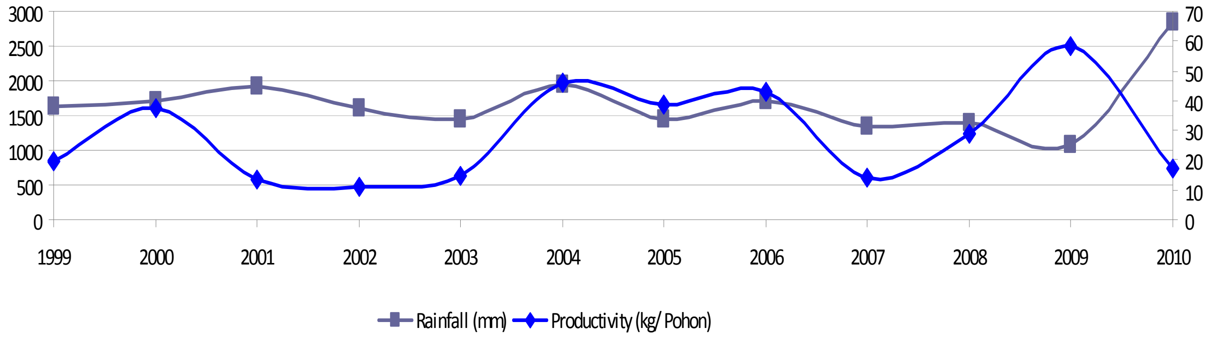

Figure A.2 Apple Productivity and Rainfall of Batu City over Time

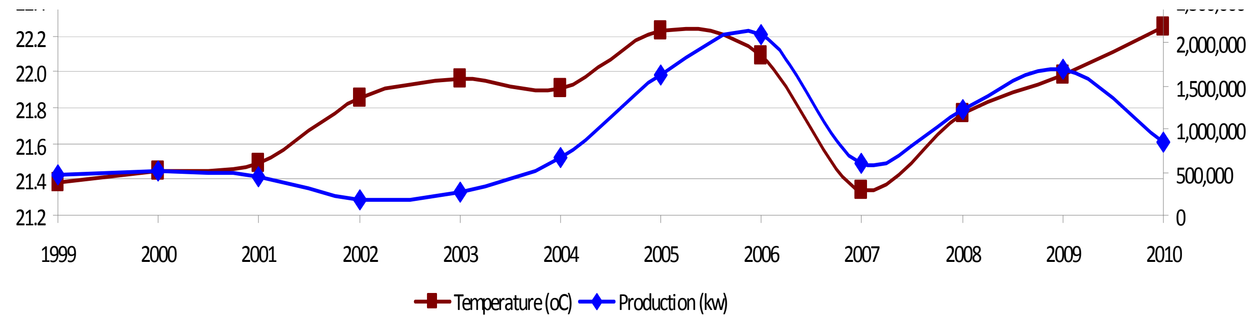

Figure A.3 Apple Production and Temperature of Batu City over Time

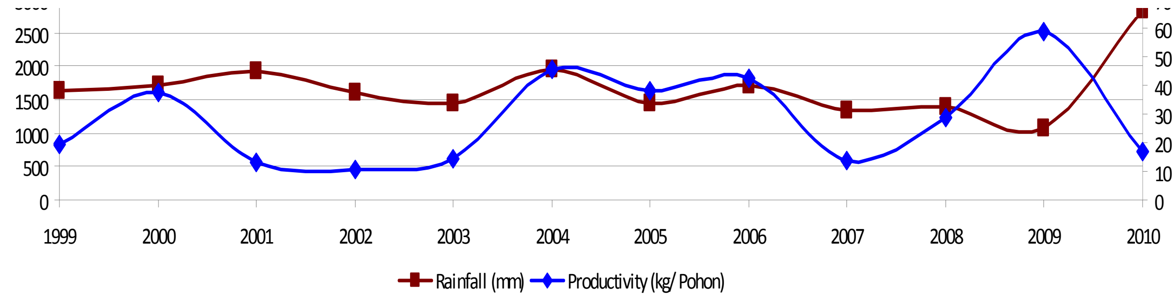

Figure A.4 Apple Production and Rainfall of Batu City over Time

A.3. Model of Relationship between Apple Productivity and Climatic Variables in Batu City

The relationship between apple productivity and temperature as well as rainfall in Batu City is not significant as shown in Table 2. The correlation between temperature and apple productivity as well as the production is positive. It shows that up to a certain limit (around 22.2^{o}C), increasing temperature may increase the apple productivity as shown in Figures 5 and 6. However, above that temperature apple production will be leveling off or even decrease. Based on Figure 6, the optimum averaged temperature for apple productivity in Batu City is 22.2^{o}C.

Meanwhile, the relationship between rainfall and apple productivity as well as its production is negative. It shows that the increasing rainfall causes the decreasing apple productivity in Batu City as shown in Figure 5 and 7. Increasing rainfall causes the flowers and young fruits fall and also the development of crop pests and diseases with the result of decreasing apple production. Based on the limited data for the relationship between apple productivity and rainfall, the optimum rainfall for apple productivity is in the range 2200 to 2800 mm per year.

Table A.2 The correlation of Apple Productivity and Production with Temperature and Rainfall of Batu City

Correlation	**Temperature**	**Rainfall**
Production of Apple	0.579	-0.239
Productivity of Apple	0.346	-0.339

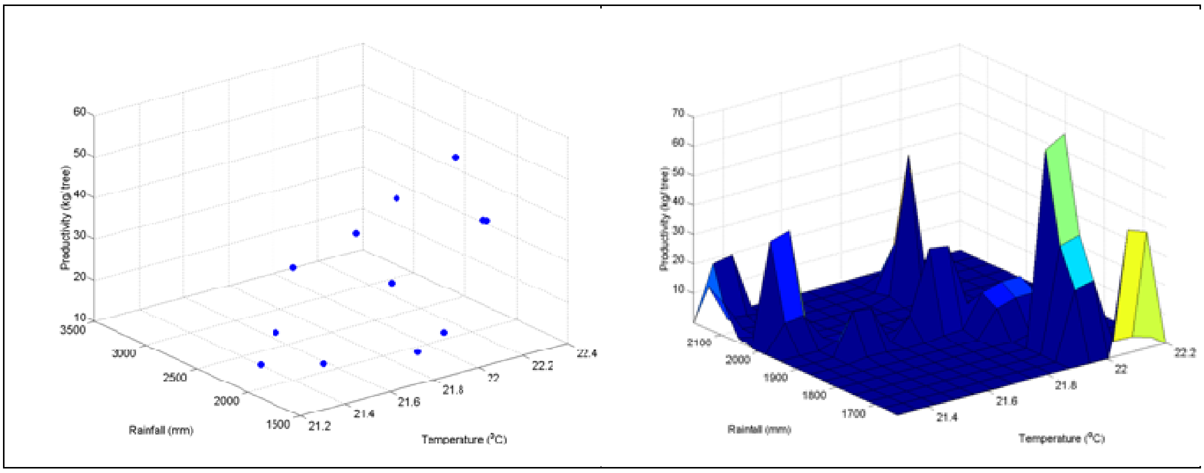

Figure A.5 The relationship of Apple Productivity and both Temperature and Rainfall of Batu City

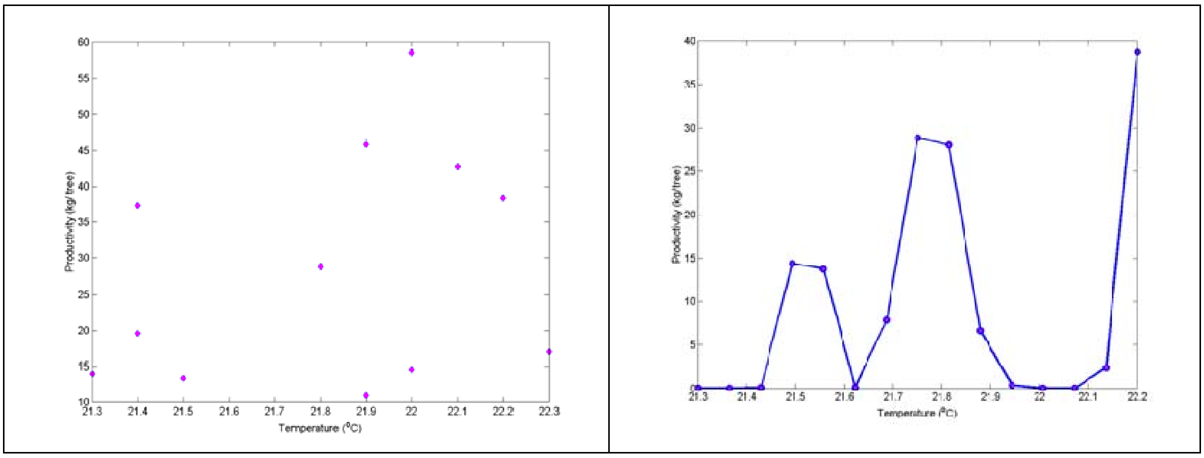

Figure A.6 The relationship between Apple Productivity and Temperature of Batu City

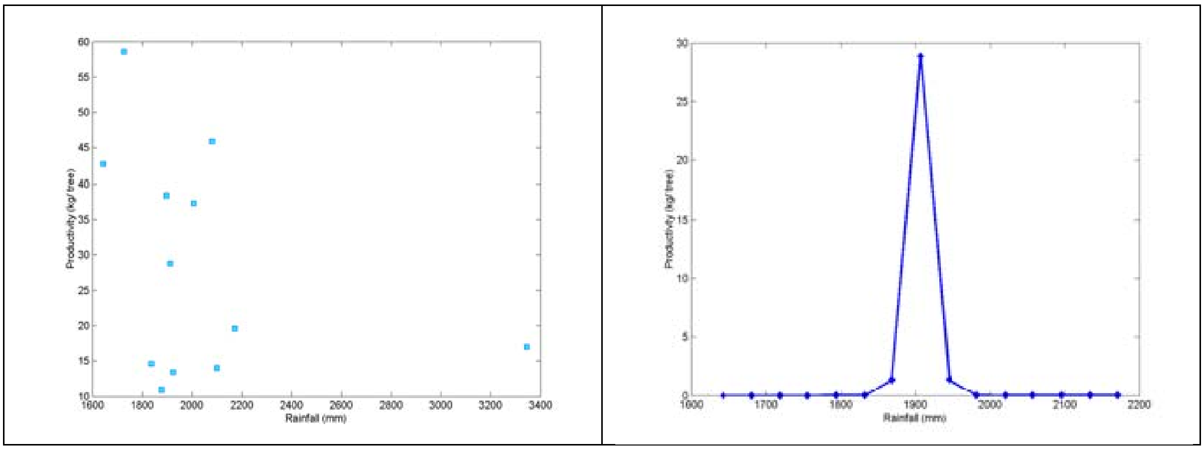

Figure A.7 The relationship between Apple Productivity and Rainfall of Batu City

A.4. Climate Change Analysis in Batu City

Based on the analysis of temperature and rainfall from 1981 to 2030 (SRA1IB Scenario), Batu City will experience climate change until 2030 as shown in Table 3. The change in climatic variables (i.e. temperature and rainfall) is represented by hytergraph as shown in Figure A. The average changes of temperature and rainfall are from 21.8^{o}C to 22.3^{O}C and from 2327 mm to 2941 mm, respectively. In terms of climate type based on Schmidth-Ferguson Classification, the Batu City area will change from climate type C (sub-tropical climate) to climate type A (wet climate).

Table A.3 Changes in Climatic Variables in Batu City

Climatic Variables	Climatic Values	
	1999-2010	2011-2030 (SRA1B)
Mean of Temperature (^{o}C)	21.8	22.3
Maximum Temperature (^{o}C)	22.5	22.8
Minimum Temperature (^{o}C)	20.8	21.2
Sum of Rainfall (mm)	2327	2941
Maximum Rainfall (mm)	325	393
Minimum Rainfall (mm)	10	68
Wet Month	7	10
Dry Month	4	0
Schmidt-Ferguson Classification	C	A

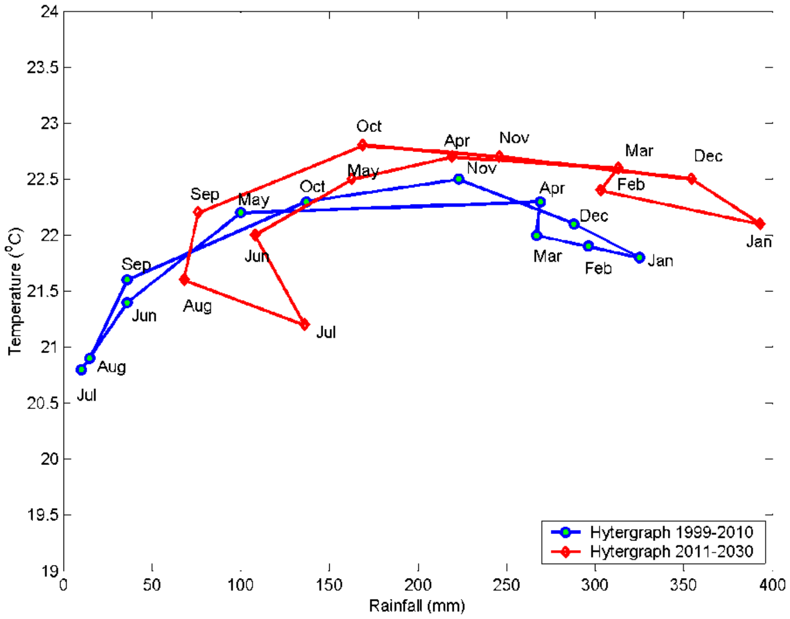

Figure A.8 Hytergraph Change of Batu City

A.5. The Issue of Apple Production Decrease in Batu City

Initially, apple plantation~~s~~ reached their peak production in the period of 1980s to 1996. According to the data from the Agency of Agriculture and Forestry of Batu City, total area of apple plantation in Batu City in 1980 is 2,015 hectares with total production of 72,000 tonnes per year resulted from 5.64 million apple trees. During the time, the apple became the mascot of Batu City. Bumiaji sub-district is the central of apple plantation beside the two others sub-districts in Batu City, Junrejo and Batu.

However, the area of apple plantation decreased afterwards. Data in 2009 showed that it remained about 600 hectare with number of apple trees is around 2.506.546, which resulted the production of only 24.625 tonnes per year. The Agency then conducted an investigation to know causes of infertility of the apple trees in Bumiaji, Sidomulyo and Punten villages. The investigation performed in 2009 concluded that there are many forest damages in Batu City resulted in increase of temperature, change of air humidity, and decrease of apple production subsequently.

The data of apple production as well as temperature and rainfall during 1999 to 2010 (Table 1) showed that the issue of apple production decrease was not entirely caused by climate change. Based on field observation, the decrease of apple production was caused by some factors below:

a. Conversion of apple plantation area to other uses (non apple).
b. Available apple crops are generally old resulted in less productive.
c. Cultivation of apple becomes less intensive so that attention of maintenance is not fully paid.
d. The apple farmers have lost their enthusiasm to cultivate the apple crop~~s~~ because its selling price decreases due to huge imported apples in the markets.

A.6. Potential of Batu Apple Production in the Future

Based on the climate projection in Batu City in 2030 (as shown in Table 3 and Figure 8), the apple production would have potential decrease in the future partly due to increases of temperature and rainfall in Batu City up to 2030. The Increase of temperature until above its optimum temperature would reduce the apple production as shown in Figure 6. Meanwhile, increment of rainfall will disturb the flowering process of the apple causing the fall of young fruits which subsequently decrease the apple production (Figure 7). Besides, the increase of rainfall would raise the air humidity, which would subsequently induce crop pests and diseases.

However, the decrease of Batu apple production caused by temperature and rainfall changes would not drastically compared with the one caused by non-climate factors such as conversion of apple plantation into areas for other business and lack of competitiveness against imported apple in the market.

A.7. Adaptation Strategies to Anticipate Production Decrease of the Batu Apple

The decrease of Batu apple production as impacts of many factors mentioned above. It is necessarily to prevent further decrease by which the icon of Batu City as a center of apple in Indonesia can be maintained. Several strategies can be implemented to achieve the aim as follows:

a. To revitalize the apple plantation areas used based on the suitability of the apple crop with the environment.
b. To plant superior types of apple seed which is able to adapt the climate change, especially temperature and rainfall changes.
c. To intensify the apple cultivation.
d. To increase the efficiency of fertilizer and pesticide uses which aims to the efforts of farm conservation and environmentally, friendly agriculture.
e. To rehabilitate apple plantation by changing old apple crop with the young ones.
f. To prevent the conversion of apple plantation areas to the non apple particularly to the non-agriculture areas.
g. To provide incentives for apple farmers so that they would still have passion to plant apple and would not change their occupations. These incentives could be promotion assistance, technical assistance for reducing production cost especially fertilizer, and market intervention for raising the selling price.