Promoting Climate Smart Sustainable Agriculture for Enhancing The Resilient of Soil Health, Rice Productivity and Food Security in Indonesia

Tualar Simarmata¹, M Khais Prayoga and Mieke R Setiawati

Department of Soil Sciences and Land resources, Faculty of Agriculture, Universitas Padjadjaran, Bandung, Indonesia

¹Email: tualar.simarmata@unpad.ac.id

Abstract. Indonesia is facing magnificent dilemma for providing food and other agricultural product to meet the food requirement of rapidly growing population and preserving land resources, health of soil ecosystem and mitigating and adapting to climate change (CC). About 70% of agricultural soils in Indonesia has been exhausted and over mined and categorized as sick soils. The impacts of CC has already hit Indonesia and caused the rise of temperature about 0.2-0.3 °C per decade and sea level (SRL) about 5 mm per year, drought and floods occur more frequently, the change of rainfall intensity and rainfall pattern, the shifting of planting season and lead to the decreasing of crops yield or yield loss significantly. The CC along coastline (95,181 km) increases and cause a severely more consequence on the livelihoods inhabitants (40% of total population) and decreasing of lowland agriculture. The paddy fields in coastal area until 2050 will decrease around 174,461 ha in Java, 8,095 ha in Bali, 78,701 ha in Sulawesi, 25,372 ha in Kalimantan, 3,170 ha in Sumatera and 2,123 ha in Lombok Island. The effort to restore and maintain the health of soil ecosystem, enhance the productivity and to mitigate and adapt to the climate change can be done by adopting climate smart sustainable agricultural (CSSA). The main objectives of CSSA are to increase the productivity and income (economically viable), improve and maintain the health soils ecosystem, build and strengthen the resilience to climate change and mitigate to reduce the GHGs. The integrated of CSSA in a climate smart sustainable farming village (CSSFV) is expected to more effective for building the resilient the soils ecosystem and farmers, mitigating and reduce the GHGS, increasing the productivity and income of the farmer and enhancing the food security in sustainable ways.

Introduction

Indonesia as an archipelagic country consisting of 17,480 islands with total coastline of 95,181 km and the 4th largest population in the word is facing serious problems for providing enough food or agricultural products, preserving environment (natural resources) and dealing with impact of climate change. The current population is about 267 million and it expected to be 480 million in the years of...
2050 (doubling size about 40 years) [1; 2; 3]. Consequently, Indonesia faces a sophisticated dilemma (cross road) between to boost the production of a sufficiently food and others agricultural products to and preserve land resource and to avoid environment hazard and disaster [4; 2]. In addition, the impacts of climate change has hit Indonesia and caused a significantly directly or indirectly reduce agricultural food production [4; 5; 6; 7]. Briefly, extreme events such as drought, heavy rainfall, flooding and high maximum temperatures and other disasters are occurring more often and lead to the decreasing of crops yield or yield loss significantly or event harvest failure. It is predicted that water availability in several places in Java, Nusa Tenggara and Sulawesi will become critical in the next 20-30 years [4; 7].

The climate change impact on agriculture highly depends on the locally specific context and hence its vulnerability. Coastal inundation due to SLR will cause serious problems along coastal zones where a large part of population (about 50-60% of total) resides. The agricultural land located near coastal areas is more vulnerable to sea level rise (SLR). It expected that the SLR by year of 2050 will reduce the paddy fields by 182,556 ha in Java and Bali, 78,701 ha in Sulawesi, 25,372 ha in Kalimantan, 3,170 ha in Sumatra, and 2,123 ha in Lombok [4; 8; 9]. It is predicted that in extreme case the rice and maize yields could decrease about <1.5 tons/ha for and soybean about <0.5 tons/ha in some areas of Java and East Nusa tenggara over the coming 20-50 years [5; 7]. The size of rice paddy fields in Java which is prone to flood/inundation reaches 1,084,217 hectares, and the extremely prone ones are 162,622 hectares, whereas in Sumatera there are 267,278 hectares, 124,465 hectares out of which are found in South Sumatera and 50,606 hectares are found in Jambi [10; 9]. Moreover, the size of area affected by flood within 16 years period (1991-2006) fluctuated with average size of damaged area of 31,977-32,826 hectares and 5,707-138,227 hectares failed to produce. It’s expected without any national effort to adapt to climate change towards year 2050, the yield strategic crops yield will decrease by 20.3-27.1% for rice paddy, 13.6% for corn, 12.4% for soybean, and 7.6% for sugar cane compared to the condition in 2006. The potentially decreasing of rice fields is reated to the declining of rice paddy field for the size of 113,003-146,473 hectares in Java, 1,314-1,345 hectares in North Sumatera, and 13,672-17,069 hectares in Sulawesi. Moreover, it is a strong indication that temperature increase is likely to continue by 0.2-0.3 °C per decade, with a total increase estimated at 0.9-2.2°C by the 2060s and 1.1-3.2 °C by 2100. Projected warming is more rapid for larger islands than for the sea and small islands. ‘Hot days’ and ‘hot nights’ are expected to occur no more by the 2060s (each compared to 10% of days/nights in the 1960s) (World Bank, 2014;). Briefly, by 2100 it is predicted that impact cost of climate change ranged 2.5-7 % of GDP [11; 7].

The intensive use of inorganic fertilizers and agrochemical products during the green revolution (at beginning year of 1960) has given a great impact on the decline of soil health and soil quality. Currently, about 70% of agricultural soils in Indonesia has a low organic content (<1.5 % of Org-C) and this lead to inefficient fertilizers uses and leveling off effect [12; 2]. The extent of critical land has reached in 2004 about 74 million hectares, consisted of 13.5 million ha as very critical, 20.1 million ha critical and 40.4 million ha belongs to slightly critical [13; 12]. Thus, most of existing agricultural lands are belong to critical land and unhealthy or sick soils. Consequently, it will have a great impact of crops production and sustainability of food security [14; 15; 2; 16]. Furthermore, decreasing of the food production is linked to the conversion of agricultural lands to non-agricultural use. It’s estimated that the rate of land conversion ranged 150,000-190,000 ha per year [2, 17].

Restoring and maintaining the soil health of degraded agricultural land and to mitigate and adapt to the climate change can be done by integrating and adopting sustainable agricultural (SA) practices and Climate Smart Agriculture (CSA). Briefly, sustainable agricultural practices are the management and conservation of the natural resource base, and the orientation of technological change in such a manner as to ensure the attainment of continued satisfaction of human needs for present and future generations. Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable” [18]. Simply, sustainable agriculture is all agricultural production systems and practices
which are economically viable, environmentally sound, and socially acceptable and which contribute to a better quality of life for agricultural producers and their families and the general public [19; 16; 20]. Furthermore, Climate-smart agriculture (CSA) is an approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change [19]. Three objectives are defined as follows; (1) sustainably increasing agricultural productivity to support equitable increases in incomes, food security and development; (2) adapting and building resilience to climate change from the farm to national levels; and (3) developing opportunities to reduce GHG emissions from agriculture compared with past trends [21; 22]. Therefore, by integrating SA and CSA become CSSA (Climate Smart Sustainable Agriculture) is strengthening the adoption of environmentally friendly agriculture (eco farming system) in sustainable ways by implementing the proper (1) sustainable soil management, (2) water management, (3) crop management and (4) mitigation and adaptation to climate change.

Critical concerns are focused on the impact of agricultural development on water availability and quality, soil degradation, air quality, greenhouse gas (GHG) emissions and climate change, and on ecosystems and biodiversity [16; 23]. Consequently, ability of agricultural practices to support the plant growth in sustainable ways are depend on soil organic management, restoring and maintaining the soils health. The basic function of healthy soils under natural ecosystems are; (1) to provide an excellence growth media for roots system and soil organisms (2) regulating and partitioning water and solute flow; (3) filtering and buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposition; (4) storing and cycling nutrients and other elements within the earth’s biosphere (5) to sustain and maintain a diverse community of soil organisms (soil biodiversity) which are important to control plant disease, insect and weed pests, to form beneficial symbiotic associations with plant roots, (6) to improve soil structure, water and nutrients holding capacity, (7) improve crop production [24; 25; 26]. Simply, soil health is reflecting the fitness of the soils ecosystem to perform their functions and as a resistance and resilience of soils in response to various stresses and disturbances.

The key success of sustainable climate agriculture (SCSA) to ensure the food security and mitigation of global climate change are highly rely on integrated soil health management to prevent problems and promote agroecosystem resilience, crop management and social engineering and management to maintain the fitness of the soil ecosystems and as well as to reduce the GHGs in sustainable ways.

**Climate Smart Sustainable Agriculture**

Increasing and boosting of agricultural production to ensure the food security sustainable ways, while and maintaining ecosystem services, mitigating and adapting to climate change and conserving biodiversity will be a defining challenge of this century [27; 28]. Intensive agricultural practices and chemical fertilizers use accelerates the soil organic carbon (SOM) mineralization, degradation of soil health or environmental health, and increases the emission of greenhouse gaseous (GHGs), such as C02 that contribute to climate change [5, 9, 29]. Meanwhile, agriculture is also vulnerable to climate change [30; 31; 32; 5; 33; 34]. Consequently, the adopting sustainable agriculture for increasing the food production without degraded the soil ecosystem is become the necessity.

Sustainable is defined as “one that produces abundant food without depleting the earth’s resources or polluting its environment [35]. Thus, sustainable agriculture practices in integrate environmental health, economic profitability, and social and economic fairness. Briefly, “Sustainable agriculture is all agricultural production systems and practices which are economically viable, environmentally sound, and socially acceptable and which contribute to a better quality of life for agricultural producers and their families and the general public [23; 36; 37]. The best practices of environmentally friendly agriculture as a multi-dimensional approach for now and the future of agriculture that enable to improve and maintain the soil ecosystem, increase the productivity and mitigate GHGs can be achieved by integrating the sustainable agriculture (SA) with the climate smart agriculture (CSA) to become Climate Smart Sustainable Agriculture (CSSA) (Figure 1).
CSA is an approach that helps to guide actions needed to transform and reorienting agricultural systems to effectively support development and ensure food security in a changing climate or under the new realities of climate change [19; 38; 39]. Briefly, CSSA can be defined as: “Agriculture that sustainably increases productivity and income, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances achievement of national food security and development goals (SDGs). The main objectives of Climate Smart Sustainable Agriculture (CSSA) and its outputs is shown in Figure 1 are Increasing the productivity and income (economically viable), Improving and maintaining the health soils ecosystem through eco-farming and soil health management (Ecologically sound), Building and strengthening the resilience to climate change and mitigating to reduce the GHGs.

**Figure 1.** Climate smart sustainable agriculture and its output for Increasing the soil health, plant health and productivity, profitability and efficiency of farming, resilient of farmer against the climate change and to reduce the GHGs emission in sustainable ways

A. Managing of Soils Health Ecosystem

Currently, most of agriculture soils either wetland ecosystem (paddy rice) or dry land ecosystem ha a low organic matter, high acidity, low nutrient content and often associated with the present toxic compound, high pH and excessive Na in Saline ecosystem. Furthermore, most of paddy soils ecosystem has been over exploited and has low nutrient content and availability, low organic content can be categorized into degraded soils or unhealthy soils [40; 13; 12]. These problems are occurred mainly due to high erosion, lack cover crops, intensive agricultural practices that accelerates the SOM mineralization and damages soil structure, over mining of soil nutrients (over exploitation), excessive of inorganic fertilizers uses, and improper cultivation technique [41; 14; 12]. In addition, climate change has made the problems more sophisticated and serious. Therefore, a comprehensive action and program must be taken to restore, improve and maintain the soil health and soil quality in sustainable ways.

The action and program to restore, improve and maintain the soils health in the frame work of CSSA should be based on integrated soil organic and integrated nutrients management in sustainable ways.

**Integrated of Soil Organic Management**

The key success of restoring and maintaining of soil health is primary depends on soil organic matter management. Organic matter (OM) is defined as any material that is derived from living organisms
(plants, animals and soil organisms) which are consists of both living parts (principally roots, soil organisms) and dead material (principally dead plant parts), including well decomposed humus. The pools of soil organic matter (SOM) can be divided into four categories: (1) living organisms and roots makes up less than 5% of total, (2) residue from dead plants, animal and soil organism that have not yet begun to decompose is less than 10%, (3) SOM is being decomposed rapidly (undergoing rapid decomposition) is about 20 – 45%), and (4) stabilized organic matter (humus) which is resistant for further decomposition is about 50 -80 % [42]. Organic matter affects significantly the biological, chemical and physical properties of the soil and its overall health. Properties influenced by organic matter include: soil structure; moisture holding capacity; diversity and activity of soil organisms, both those that are beneficial and harmful to crop production; and nutrient availability. Organic matter is also act as the store house for the energy and nutrients used by plants and other organisms [24; 35; 25]).

Briefly, the main functions of OM in soils are; (a) as a. revolving nutrient bank account. Soil organic matter is derived mainly from plant residues and it contain all essential plant nutrients (macro and micronutrients) and chemical energy resulted from photosynthesis. Therefore, accumulated’ organic matter is storehouse for nutrients and chemical energy. Either nutrients or energy are released by microbial process (mineralization or decomposition and oxidation of organic substances). The released nutrients are highly to plant (plant-available form) and the stable organic fraction (humus) adsorbs and holds nutrients in a plant-available form. Furthermore, If the rate of addition organic matter into soil (plant residue, fertilizers and etc.) is less than the rate of decomposition, soil organic matter will decline, and if the rate of addition is greater than the rate of decomposition, soil organic matter will increase, (b) as entry point of energy flow (supply) into soils ecosystem, (c) As an agent to activate and regulate the biological system in soils, and (d) as an agent to improve soil structure, maintain tilth and minimize erosion [24; 12].

Consequently, organic matter plays an important and vital role in soils ecosystems and it may categorize as heart of soil ecosystem. Soil as a living system is absolutely depends on supply and availability of organic matter which act as fuel for soil as bioreactor. Thus, low supply or low content of SOM will disturb the energy flow (food web) and led to unhealthy soils (dead or sick soils). Soil organic matter is utilized by soil organisms, mainly as source of energy. Therefore, SOM is subject to decomposition and highly affect by the soil organism activity. Under favorable condition, such suitable soil moisture content and nutrient availability, especially nitrogen the decomposition goes rapidly and it may cause the declining of SOM in soils sharply. Agricultural practices under continuous management cause the decrease of soil health gradually. In addition, under improper management the soils health will be decreased sharply and in short time the fertile and healthy soils turn become a sick soils or degraded soils [43; 12].

Consequently, the adding of organic material through organic fertilizers, plant residue or green manure is necessary for restoring and improving the soils health. Integrated soil organic management can be adopted to maintain the organic carbon more than 2%. This including re-use of crops residue, using organic mulch or cover crops, efficient fertilizers use, crop rotation or multiple crops, conservation tillage and combined with others good agricultural practices. Practically about 5 -10 ton/ha organic fertilizers (green manure, compost, manure, plant residue) 1 is need to fuel energy supply into soil ecosystems. This high dosage of organic demand can be secured only by good organic management, such recycling process of plant residue surrounding cultivated land.

Restoring the soil health paddy soils ecosystem is relative easier than dry land agriculture, particularly for managing the soil organic matter. The production of organic manure in form straw is about 10 – 15-ton straw per hectare per season (normally about 1.5 x grain yield) and can be composted to result about 4 – 5 ton of straw compost/ha. By returning this compost into soil, the organic carbon can be maintained at levels of healthy soils. Furthermore, the application of straw compost about 2 – 4 ton/ha or straw 5 – 10 ton/ha increases the growth and grain yield of paddy rice and reduce the rate of inorganic fertilizers significantly. In addition, the application of green manure (Azolla and Sesbania) which make a symbiosis with nitrogen fixer bacteria is recommended to provide the green manure and to reduce the inorganic nitrogen fertilizers [44; 14]).
Integrated nutrients Management (INM)

Integrated nutrient management (INM) system aims at achieving efficient use of chemical fertilizers in conjunction with organic manures. Briefly, primary goals of INM is to integrate all methods of nutrient management into ecologically sound and economically viable farming systems that utilize available organic and inorganic sources of nutrients in a judicious and efficient way [45; 46; 47]. INM optimizes all aspects of nutrient cycling. It attempts to achieve tight nutrient cycling with synchrony between nutrient demand by the crop and nutrient release in the soil, while minimizing losses through leaching, runoff, volatilization and immobilization [48; 49]. The adopting of INM in modern and eco-friendly agriculture is become more important due to (a) degradation of soil health and plant productivity (leveling off), (b) imbalance in the ratio of NPK consumption and high price of chemical fertilizers increases continually, (c) consumption of non-renewable energy sources by inorganic fertilizers increases continually; (d) pollution hazards of chemical fertilizers and mineral fertilizers has treated the environments quality (e) organic fertilizers has multifunctional purposes such as soil remediating agent and ameliorant, source complete nutrients, act as fuel for soil food web, improve and maintain the function of soils as natural bioreactor or biofertilizers factory [50; 24; 12; 2]).

Briefly, a good integrated soil organic management and nutrients management combined with others best management or good agricultural practices (integrated soil and water conservation, integrated pest management are the main success key of restoring and maintaining of soils health for sustainable agricultural practices (Kinyangi, 2007 [51; 46; 49; 52]).

Building the Resilient of Soil Health

The key success of building the resilient depends on soil health and quality management [2], as summarized below; (1) Enhance and maintain organic matter. The adding new organic matter and maintain the OM content above 2-3% is required to improve and maintain soil quality. Regular additions of organic matter (recycling the residue, organic fertilizers, green manure, crop rotation, minimum tillage etc..) improve soil structure, enhance water and nutrient holding capacity, protect soil from erosion and compaction, and support a healthy community of soil organisms, (2) Minimum tillage reducing tillage minimizes the loss of organic matter and protects the soil surface with plant residue., (3) Use nutrients efficiently is the key point of best soil management, thus only the necessary chemicals, at the right time and place to get the job done; and taking advantage of non-chemical approaches to pest and nutrient management such as crop rotations, cover crops, and manure management. In addition, the organic based nutrient management is highly recommended, (4) Prevent soil compaction: Compaction reduces the amount of air, water, and space available to roots and soil organisms, (5) Keep the ground covered: using mulch, crops or growing the cover crops (legume cover crops) to protects soil, provides habitats for larger soil organisms, such as insects and earthworms, and can improve water availability, (6) Diversify cropping systems and crop rotation: Diversity of cropping system contributes to improve the resilient of soils health and soil ecosystem. A diversity of soil organisms can help control pest populations and enhance the plant health. In addition, multiple cropping system and rotation improves the efficiency of nutrient uses.

B. Climate Smart Sustainable Farming Village (CSSFV)

In some country they are working with communities to develop ‘Climate-Smart Villages’. Climate smart model is a places where researchers, local partners, and farmers collaborate to evaluate and maximize synergies across a portfolio of climate-smart agricultural interventions. Its aim to improve farmers’ income and resilience to climatic risks and boost their ability to adapt to climate change.

Climate smart sustainable farming village (CSSV) is the place village where local communities (farmers researcher, farmer groups) work together with the researchers, policymakers, scientists, NGO, s and development workers or others stakeholder to develop a strategic approach to climate smart sustainable agriculture [21; 53]. Collaborating to make the plan, perform or act, coordinate, control or
evaluate and synchronize the program (portfolio) of climate-smart environmentally friendly farming and management of soil health for improving farmers' income, resilience to climatic risks and enhance their knowledge and ability to adapt to climate change. The main strategy are including: (1) Adopting and integrating the farmers participatory approach, (2) Integrating the local knowledge and local adapted crops, (3) Improving and strengthening the capacity of farmers, (4) adopting and implementing the sustainable crop and soils health management, (4) using the appropriate smart technology and modern information computer technology (ICT) tools.

The priority activity in village levels of CSSA to build the resilient of the farmer and the soil ecosystem shall concentrate on: (1) Adjusting the planting pattern and cropping patterns, (2) Selection of superior climate-change-resistant types of seeds, (3) Agricultural diversification and food cropping/diversification, (4) Managing efficiently the fertilizers use, planting fields and water use, (5) Adopting and implementing organic based fertilizers (organic dung, compost, biochar, biofertilizers, green manure and others natural nutrients resources), (6) Develop the soils health and plant clinic for monitoring, improve and maintain the soils health ecosystem in sustainable ways, (7) Developing agricultural information system for production system and marketing, (8) Developing agricultural insurance system, (9) Building the farmer capacity through workshop, information exchange, training, seminar and other scientific activity, (10) Supporting innovative activity in the community and Using the ICT tools to support all the activity including marketing and branding image

Key component in CSSFV are focused on: (1) smart climate and water management, (2) smart carbon and nutrient management, (3) smart yield and risk management, and smart community or smart knowledge (Table 1).

Table 1. Main focus on climate smart sustainable farming village to build the resilient in adapting to climate change and mitigate the GHGs

| SMART                                      | Climate and Water                                           | Carbon and Nutrients                  | Yield and Risk                        | Community & Knowledge                     |
|--------------------------------------------|-------------------------------------------------------------|---------------------------------------|---------------------------------------|------------------------------------------|
| **Climate Smart Technology**               | Soil health management                                      | Tolerant or adapted variety (floods, salinity, toxicity, etc.) | Climate field farmer school           |
| Climate smart information (Rainfall, W forecasting, etc.) | Organic dan natural based fertilizers | Management of Salinity and toxicity; Soil health and plant growth; pest and diseases, and etc. | Soil health Clinic                    |
| Water saving technology                     | Residue management                                           |                                       | Farmer networks                       |
| Rain water harvesting                      | SOM management                                              |                                       | TOT                                    |
| Community water management                  | Zero or minimum tillage, soil and conservation               |                                       | Extension workers                     |
| On farm water managements                  | Livestock management                                        |                                       | Farmers consultant                    |
|                                            | Site specific nutrient management                            |                                       | Researchers                            |
|                                            | Efficient fertilizers use                                   |                                       | Govt. or NGO consultancy              |
|                                            | Cropping system                                             |                                       | Others agency or partnership, etc.    |

Best Use of ICT Tools and Mobile Phone Applications
Conclusion
The climate change is severely hit in Indonesia and lead to more frequent droughts, heat waves, floods and other disaster. About 40% of Indonesia’s population is highly vulnerable to impacts of climate change. The rainfall pattern, intensity and shifting of cropping season are changing and its causes a significantly loss of agricultural product and it threatens the food security. The rising of temperature about 0.2-0.3 per decade (estimated at 0.9-2.2°C by the 2060s and 1.1-3.2 °C by 2100) and level see rise (LSR) about 5 mm per year are increasing impact of CC, particularly for inhabitant on lowland area along 91,000 km of coastline. SLR by year of 2050 will reduce the paddy fields by 182,556 ha in Java and Bali, 78,701 ha in Sulawesi, 25,372 ha in Kalimantan, 3,170 ha in Sumatra, and 2,123 ha in Lombok. Moreover, without any national effort to adapt to CC towards year 2050, the yield strategic crops yield will decrease by 20.3-27.1% for rice paddy, 13.6% for corn, 12.4% for soybean, and 7.6% for sugar. Its estimate hat that climate change impacts will cost about 2.5-7% of GDP by the of 2100. Briefly, the food security, water availability and livelihood will be heavily affected by temperature increase, shorter growing season, unpredictable rainfall, and salt-water intrusion.

Most of the agricultural soils has low organic matter, low pH, low nutrient availability and highly exhausted has been classified as sick soils (unhealthy). Climate Smart Sustainable Agriculture (CSSA) can be adopted for improving, maintaining the soil health, crop productivity and increasing the resilience of soil ecosystem and the farmer against the climate change. The integrated of CSSA in a climate smart sustainable farming village (CSSFV) is expected to more effective for building the resilient the soils ecosystem and farmers, mitigating and reduce the GHGS, increasing the productivity and income of the farmer and enhancing the food security in sustainable ways.

References
[1] BPS 2019 Bureau of Indonesian Statistic https://www.bps.go.id/
[2] Simarmata T, Setiawati M R, Herdiantoro D and B N Fitriatin 2018 Managing of Organic-Biofertilizers Nutrient Based and Water Saving Technology for Restoring the Soil Health and Enhancing the Sustainability of Rice Production in Indonesia. IOP Conf. Series: Earth and Environmental Science 205 (2018) 012051
[3] Rosenberg M 2019. Current World Population http://geography.about.com/od/obtainpopulationdata/a/worldpopulation.htm
[4] National Development Planning Agency 2010 Indonesia Climate Change Sectoral Roadmap; Agriculture sector Ministry of National Development Planning Jakarta
[5] BAPPENAS (National Development Planning Agency) 2011 Indonesia Adaptation Strategy Improving Capacity to Adapt Ministry of National Development Planning Jakarta
[6] Yunita T W., K. Stigter, E. Anantasari and S. N. Hidayah 2017 Climate Field Schools in Indonesia: Improving “response farming” to climate change. /s4.
[7] FAO 2017 Voluntary Guidelines for Sustainable Soil Management Food and Agriculture Organization of the United Nations Rome, Italy. www.fao.org/publications and can be purchased through publications-sales@fao.org.
[8] Climate Service Center (CSC) 2015 Climate Fact Sheet – Indonesia, updated version 2015 http://www.climate-service-center.de/products_and_publications/fact_sheets/climate_fact_sheets/index.php.en
[9] Ministry of Foreign Affairs of the Netherlands (MFAN) 2018 Climate Change Profile Indonesia. Published by:Ministry of Foreign Affairs of the Netherlands
[10] BAPPENAS (National Development Planning Agency) 2018 Indonesia Climate Change Sectoral Roadmap; Agriculture sector Ministry of National Development Planning Jakarta
[11] World Bank 2014 Climate Change and Water Resources in Indonesia (2009): Country Report
[12] Simarmata T, Hersanti, Turmikutini T, Fitriatin B N, Setiawati M R, and Purwanto 2017 Application of Bioameliorant and Biofertilizers to Increase the Soil Health and Rice Productivity HAYATI Journal of Biosciences 23 (2016): 181-184
[13] Agus F. Wahyunto, Robert L Watung, Sidik H Tala’ouh, and Sutono 2016 Land Use Changes and Their Effects on Environmental Functions of Agriculture. https://www.researchgate.net/publication/266370154

[14] Simarmata T, B Joy and T Turmuktini 2011 Management of Water Saving And Organic Based Fertilizers Technology for Remediation and Maintaining The Health of Paddy Soils And To Increase The Sustainability of Rice Productivity In Indonesia. Call Paper on Conference of Sustainable Agriculture and Food security: Challenge and Opportunities, 27 – 28 September 2011, University of Padjadjaran Bandung – Indonesia

[15] Lassa J A, Mau YS, Li D E, and N Frans 2014 Impact of Climate Change on Agriculture and Food Crops: Options for Climate Smart Agriculture and Local Adaptation in East Nusa Tenggara, Indonesia. IRGSC Working paper 8

[16] Renee Cho 2018 How Climate Change Will Alter Our Food https://blogs.ei.columbia.edu/2018/07/25/climate-change-food-agriculture/

[17] Rondhi M, P A Pratiwi, V T Handini, A F Sunartomo and S A. Budiman 2018 Agricultural Land Conversion, Land Economic Value, and Sustainable Agriculture: A Case Study in East Java, Indonesia. Journal of MDPI: land vol 7 (148): 1 – 9

[18] FAO 1988 Report of the FAO Council. 94th Session 1988 Food and Agriculture Organization of The United Nation, Rome

[19] FAO 2019 Sustainable agriculture and rural development Food and Agriculture Organization of The United Nation, Rome

[20] HLPE 2016 Sustainable agricultural development for food security and nutrition: what roles for livestock? All HLPE reports are available at www.fao.org/cfs/cfs-hlpe

[21] FAO 2013 Climate-Smart Agriculture Sourcebook Executive Summary. Indonesian farmers gear up to face the challenges of climate change. http://www.fao.org/indonesia/news/detail-events/ru/c/1110775/

[22] FAO 2014 Building a common vision for sustainable food and agriculture Principles and Approaches Food and Agriculture Organization of The United Nation, Rome

[23] FAO 2010 Climate-smart Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation Food and Agriculture Organization of The United Nation, Rome

[24] Ingham E R 2001 The food web and soil health. Soil Biology Primer [online] www.statlab.iastate.edu/survey/SQI/soil_biology_primer.htm

[25] Doran J W 2002 Soil health and global sustainability: translating science into practice Agriculture, Ecosystem & Environment 88, 119–127

[26] Dey P 2016 Soil health management In: Soil Health: Concept, Status and Monitoring (Eds. Katyal, J C, Chaudhari, S K, Divedi, B S, Biswas, D R, Rattan, R K and Majumdar, K). Bulletin of the Indian Society of Soil Science 30, pp. 79-97.

[27] Blaser W J, J Oppong, J Hart, S P Landolt, J Yeboa E and J Six 2018 Climate-smart sustainable agriculture in low-to-intermediate shade agroforest Nature Sustainability vol 1: 234–239

[28] FAO 2018 Climate Change Resilience and Disaster Risk Reduction in Haiti After the Earthquake Food and Agriculture Organization of The United Nations Office of Evaluation http://www.fao.org/evaluation

[29] Stanford 2017 Climate change a threat to Indonesian agriculture, study says https://news.stanford.edu/news/2007/may9/indonesiasr-050907.html

[30] Parry M, Evans A, Rosegrant M W and T Wheeler 2009 Climate Change and Hunger: Responding to the Challenge World Food Programme, Rome, 2009

[31] Morton J F 2007 The impact of climate change on smallholder and subsistence agriculture Proc. Natl Acad. Sci. USA 104, 19680–19685

[32] IPCC 2014 Mitigation of Climate Change Final draft Report of Working Group III Contribution to the Fourth Assessment Report of the IPCC Sustainable agricultural development for food security and nutrition
[33] Mumtaz M, de Oliveira J A P and S H Ali 2019 Climate Change Impacts and Adaptation in Agricultural Sector: The Case of Local Responses in Punjab, Pakistan [Online First]. IntechOpen, DOI: 10.5772/intechopen.83553

[34] Ahmed I, Ullah A, Habibur Rahman, M Ahmad, B Wajid, S A Ahmad and S Ahmed 2019 Climate Change Impacts and Adaptation Strategies for Agronomic Crops [Online First]. IntechOpen, DOI: 10.5772/intechopen.82697

[35] Sullivan P 2004 Sustainable Soil Management. National Sustainable Agriculture Information Service. Available www.attra.ncat.org

[36] Branca G, Mc Carthy, N Lipper L and M C Jolejole 2011 Climate Smart Agriculture: A synthesis of Empirical Evidence of Food Security and Mitigation Benefits from Improved Cropland Management. http://www.fao.org/climatechange/29764-0aa5796a4f093b6cfdff05558c6dd20bb.pdf

[37] FAO 2017 Indonesian farmers gear up to face the challenges of climate change. Food and Agriculture Organization of the United Nation, Rome

[38] Lipper L, P K Thornton, B M Campbell, and T Baedeker 2014 Climate-smart agriculture for food security Nature Climate Change vol 4: 1068 – 1072

[39] Steenwerth, K L, Hodson A K, Bloom A J, Carter M R, Cattaneo A, Chartres C J, and Jenkins B M 2014 Climate-smart agriculture global research agenda: scientific basis for action Agriculture and Food Security vol 3(1): 11

[40] Dobermann A and T H Fairhurst 2002 Rice Straw Management Better Crops International Vol. 16 Special Supplement May 2002

[41] Bot A and J Benites 2005 The importance of soil organic matter Key to drought-resistant soil and sustained food production. Food and Agriculture Organization of The United Nations. http://www.fao.org/docrep/009/a0100e/a0100e00.htm

[42] Moravec M, D Whiting, A Card and C Wilson 2009 The Living Soil Colorado State University. http://cmg.colostate.edu/gardenotes/212.pdf

[43] Bunning S and J J Jiménez 2003 Indicators and Assessment of Soil Biodiversity/Soil Ecosystem Functioning for Farmers and Governments. Paper presented at the OECD Expert Meeting on indicators of Soil Erosion and Soil Biodiversity 25–28 March 2003, Rome, Italy. www.fao.org/landandwater/agll/soilbiod/docs/OECDpaper_final.doc

[44] Simarmata T 2013 Tropical Bioresources to Support Biofertilizer Industry and Sustainable Agriculture In Indonesia Invited and presented Paper for International Seminar on Tropical Bio-resources for Sustainable Bioindustry 2013; from Basic Research to Industry, 30 – 31st October 2013 in West and East Hall – ITB-Bandung-Indonesia. https://www.researchgate.net/profile/Tualar_Simarmata/publications/?lnkType=fulltextFile&ev=prf_pubs_file

[45] Suresh K, Reddy G R, Hemalatha S, Reddy S N, Raju A S and T Y Madhulety 2013 Integrated Nutrient Management In Rice: A Critical Review. International Journal Of Applied Biology And Pharmaceutical Technology Page: 47. Available online at www.ijabpt.com

[46] Wu W and B Ma 2015 Integrated nutrient management (INM) for sustaining crop productivity and reducing environmental impact: A review. Science of The Total Environment. Volumes 512–513, 15 April 2015, Pages 415–427. https://doi.org/10.1016/j.scitotenv.2014.12.101

[47] Pradip D, Sanjay Srivastava, Lenka N K, Shinogi K C, Vishwakarma A K and A K. Patra (Eds.) 2018 SAARC Training Manual on Integrated Nutrient Management for Improving Soil Health and Crop Productivity ICAR-Indian Institute of Soil Science, Bhopal, India

[48] Basavaneppa M A and Biradar D P 2002 Integrated nutrient management practices on the production of cotton-maize-bengal gram sequence under irrigated ecosystem in Tungabhadra Project area J. Cot. Res. Dev.16:125-9

[49] Sindhi S J, Thanki J D and L J Desai 2018 A review on integrated nutrient management (INM) approach for maize Journal of Pharmacognosy and Phytochemistry 2018; 7(4): 3266 – 3269
[50] Mahajan A, R M Bhagat and R D Gupta 2008 Integrated nutrient management in sustainable rice-wheat cropping system for food security in India SAARC J. Agric vol 6: 29 – 32
[51] Kinyangi J 2007 Soil health and soil quality: a review www. worldaginfo. org/files/Soil%2520Health%2520Review.pdf
[52] Shah F and W Wu 2019 Soil and Crop Management Strategies to Ensure Higher Crop Productivity within Sustainable Environments Sustainability 2019, 11, 1485; doi:10.3390/su11051485. www.mdpi.com/journal/sustainability
[53] Kumar S and R Jangir 2018 Climate Smart Village: A Model for Sustainable Agricultural Development Indian Journal of Ecology (2017) 44 Special Issue (6): 615 – 618