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Empowering upland farmers to become more resilient towards climate change – experiences from Toraja, Indonesia

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Abstract. Climate change is a factual phenomenon which is currently occurring and has affected every part of the world. It is disastrous in agriculture as in long term the harvest failure and diminishing farmland could result in food shortage hence world crisis. Farmers are most susceptible, therefore helping them to prepare, adapt and mitigate the impact of climate change become essential. This paper presents the factual climate-related problems in agriculture. It also shows stages of activity conducted by collaboration of farmers, university and NGO in stimulating and empowering farmers to be more aware, ready, smart and capable in proposing efforts of adaptation for their farms. The process acknowledged that farmers are also curious for field experiment before a technology can be fully adopted by them.

1. Introduction

Climate change poses various threats to the agricultural sector and affects the sustainability of food production through a series of newly emerging problems [1]. In Indonesia, all sectors climate changes affects all sectors, with the agriculture sector experiences the most serious impacts for several reasons. Many resource-poor households are involved in agriculture and depend on rain-fed farming [2]. Farmers already suffer from declining yields and crop failures among others [3]. Various bio-physical impacts from climate change influence the physical and biological systems of the environment [4] and these changes highly affect farm management decisions on seed varieties, soil fertility management and pest and diseases control [2]. Bio-physical impacts are observed in the category of climate with unstable precipitation patterns and changed wind patterns, rising temperatures, increased salinity through sea level rise; in the category of hazards with increased intensity of tropical storms, landslides by increased heavy rainfall events. Agriculture is directly impacted by changes in the reproduction behaviors of animals and plants, distribution of species and population size and increased frequency of plant pests and diseases [4]. These bio-physical factors threaten the food security and make Indonesia highly vulnerable to climate change [1].

Considering climate as one main factor for plant's metabolism and physiology, global warming has detrimental effect on the sustainability of agricultural development [5].



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Climate change affects the way farmers manage irrigated and rain-fed paddy land. Changing and influential elements in land management include the scheduling of irrigation water, which is often late due to changing patterns and erratic distribution of rainfall. This irregularity often destroys rice nurseries and tends to increase the intensity of pest attacks in paddy fields and shorter planting seasons for rice [6].

A study by [7] shows the significance to address the issue of climate change and the need to raise farmers' awareness of climate change. Generally, there is a lack of farmers' understanding of what climate change really means and how it affects their farming systems. There have been efforts to support farmers in adapting to climate change, how to adapt with farm-level strategies to better manage the microclimate in their farms.

Indonesia has two distinct seasons, the wet and the dry season, which varies across agro-ecological regions in terms of time of occurrence and duration of the event. The western part of Indonesia is mainly influenced by the Asian weather situation in the rainy season, while its eastern part is determined by the general weather situation from Australia in the dry season. The latter macro weather also applies for South Sulawesi. During the previous decade, South Sulawesi has experienced a significant climate change compared to earlier situations, which results in various problems and losses in agriculture [8].

This paper aims at describing the impacts of climate change on agriculture and farmers in the specific region of South Sulawesi, as well as analyzing the impact and value of adaptation strategies carried out by farmers. It also reflects on a participatory research process conducted with farmers in Tana Toraja, a hilly upland region in South Sulawesi. In this process, farm-level adaptation strategies are assessed by farmer field trials. These farmer field trials are set up and managed in so-called farmer climate field labs, a specific form of citizen science [9] (X). In this field research farmers act as farmer researchers conducting research as non-academia by designing treatments, collecting and analyzing data and developing location-specific solutions for their farm to address their climate change related needs.

2. Impacts of Climate Change on Agriculture

There are many studies that describe the climatic factors, which affect agriculture in general. Depending on the perspective, the community differentiates between agriculture as contributing sector to accelerate global warming and agriculture as suffering sector factor. While the contribution of direct emissions from the agricultural sector is relatively small, the impact that the sector feels in return could be massive [2].

According to [10], three main global climate change factors have impacts on the Indonesian agricultural sector, which are: 1) changes in rainfall patterns, 2) increased hazards (floods and droughts), and 3) increased air and sea surface temperatures. Pointing specifically to rising sea levels, the losses of coastal land are high in specific islands of the archipelago (i.e. Java, Bali, North Sumatra, Lampung, West Nusa Tenggara and Kalimantan). Salt water intrusion causes serious damage to agricultural infrastructure and land degradation through salinization, which is detrimental for crops [5]. In general, the effects of climate change to agriculture are due to two main factors:

2.1. Temperature

The influence of climate change on temperature can be seen from the occurrence of anomalies in global air temperatures on the Earth's surface over the last hundred years [11], the trend with scientific credential is factual temperature increase [4]. The increase in global air temperature over the past 100 years was 0.57°C in average [12]. In Asia there has been a reported increase in temperature of 1°C-3°C, and in Indonesia there has been a moderate rise in temperature of 0.3°C in the last decade [3].

The increase in temperature causes an increase in transpiration which further decreases the productivity of food crops [5], increased water consumption, accelerated maturation of fruits/seeds, reduced quality of yields and a more encouraging environment for the development of pests and diseases [2]. According to a study on three different altitudes in Indonesia, a temperature rise up to 2°C in uplands and highlands cause a production decrease by about 20% [13].

17. Disruption of Hydrological cycle

Climate change is characterized by changes in rainfall patterns that cause a shift in the beginning of the planting season, making it difficult to plan crop cultivation [14]. Research by [15] showed that the number of months with extreme rainfall tends to increase in last 50 years.

Disruption in hydrological cycle resulted in a longer dry season and a more intensive but shorter rainy season, increasing cycles of dry and rainy anomalies and decreasing soil moisture. These all will disrupt the agricultural sector, which is likely to decrease crop yields due to the increasing dry land in a longer dry season [16]

The instability of rainfall is also one of the main factors that can affect the productivity of food crops, especially rice in Indonesia. An increase in rainfall will have a positive impact to a certain point, yet excessive rainfall will have a negative impact on rice productivity [17]

Climate change causes the seasons to become erratic and weather is more difficult to predict [18]. This is caused by changes that occur in elements of climate and weather [1,19] Changes in these climate elements are very likely to encourage shifts in the climate zone [20] which results in changes in cropping patterns and patterns of agricultural production [16].

3. Farmers Knowledge and adaptation on Climate Change

Most all agricultural sub-sectors, especially horticulture and livestock, have a high risk of being affected by the effects of climate change [1]. Therefore, farmers are the frail party to bear the consequences.

In general, the level of knowledge of climate change adaptation for most farmers is relatively not comparable with the impact of observable climate change. A research by [18] seen a small number of farmers with knowledge of adaptation strategies. In other research by [21] quite significant farmers already realized the incidence of climate change, yet very few of them have taken adaptation measures.

Adaptation by definition is adjustment in various system of fields such as ecology, social or economy as a measure to respond to observable changes in climatic stimuli in order to mitigate the impacts of these changes as well as make an opportunity out of them [22]. The ability of farmers to adapt in overcoming the effects of climate change is becoming increasingly important to reduce the losses. Adaptation to climate change can be interpreted as a form of response adjustments made to address the effects of climate change [23]

A research by [18] found knowledge of farmers' climate change adaptation is relatively low, especially regarding rice paddy varieties that are tolerant of flood, drought, or certain pests as well as other superior varieties that can be planted as a strategy to reduce the negative impacts of climate change. Majority of those farmers were also wonder why pests and diseases were more intense in their farm lately.

4. A Process of Learning and Solving: A Case of Torajan Farmers in Responding to Farm Challenges related to Climate Change

Tana Toraja has geographically hilly region, hence is considered to be one of frail areas against the climate change. The observable conditions such as shift in rainfall pattern, solar radiation, humidity and temperature. Apart from direct effect of climate-related disaster such as landslides, flooding, drought, etc, the climate change affect farmers in Toraja through declining farms yield due to extreme climatic condition that is unfavourable and even detrimental for plants. Agriculture is a sector that can contribute to as well as be affected by climate change [1] [6].

Recognizing the importance of farmers understanding the phenomenon of climate change and conducting mitigation and adaptation actions, farmers in Toraja with the help of NGOs (MTV-Pusbinlat) and university (Universitas Hasanuddin) work together in an activity: 'Climate Resilient Agriculture Innovation Investigation Project' (CRAIP). In this project the NGO facilitates farmers to obtain guidance from universities in addressing the phenomenon of climate change. Various activities carried out are described in the following stages.

The flow of activities is seen in Figure 1.

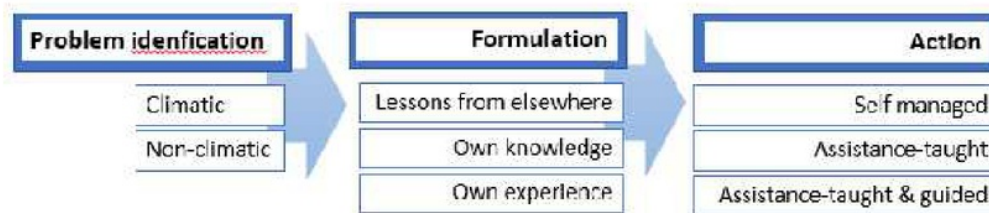


Figure 1. Activity stages of farmer-led research

4.1. Understanding the problems

After learning experiences from other places and based on what was experienced by the farmers themselves, through a Focus Group Discussion (FGD), Torajan farmers were asked to identify the agriculture-related problems they have. As a way to ease the identification process, before the FGD the teams from university and NGO have performed survey and identification which will then enrich material for discussion with farmers.

First of all, through this process farmers were required to express their feeling and observation towards the climatic atmosphere. The results is presented in Table 2.

Table 1. Climatic variability and changes-farmers perceiveness

CLIMATE VARIABILITY AND CHANGE (How our weather has changed in 30 years)		Villages			
	Bua' Tarrung	Batu Sura'	To' Pao	Tallang Sura'	Buntu Datu
1	How do you feel that the day time temperature has changed in your village?	Hotter	Hot	Hot	Hotter
2	How do you feel that the night time temperature has changed in your village?	Hotter	Very cold	Cold	Colder, especially in the dry season
3	How has the overall annual rainfall changed?	Increasing	Higher rainfall	Rainfall is unpredictable	Higher
4	In which months do you have more rain than usual?	December - August	End of October to January	January - June	October - May
5	In which months do you have less rain than usual?	September - November	April to June	August - November	June - September
6	Do you have traditional weather rules in your village?	Full moon	Thick cloud over Mt. Sado'ko, birds singing, Marble-shaped mango flowers	Dec-Jun = Rainy season July-Aug = light rain Aug-Nov = Dry season	None
7	Can you rely on these rules? If not, what has changed?	less reliable	No	Yes	No
8	Explain any changes about the start of the rainy season. Does it start earlier or later? With heavy or light rain?	Earlier and doesn't start with heavy rain	Starts with light spots of rain, becoming heavier	High temperature, thunderstorms, wind from the south	Overcast, windy and thunderstorms. Usually heavy rain accompanied by strong winds
9	Do you experience more or less dry spells during beginning of rainy season?	Yes?		A little less?	A little?
10	How does it affect your plants?	Reduced yield	More diseases and pests	influential	Tomato fruit and stems rot, green mustard eaten by caterpillars

4.2. Developing Ideas

After climatic change identification, farmers also identify problems they perceive in their farms which they think related with climate. With the guidance from university during the FGD, farmers also suggested ideas on how to investigate more about the problem or further how to overcome the problems. The result of this process can be seen in Table 2.

Table 2. Impacts of climate change and new ideas for adaptation-farmers perceiveness

No	Impacts of Climate Change on Agriculture	New Ideas for Adaptation / Best Practice (from where?)	Activities in the target Village	Output Expected
1	Increase soil acidity (content of acid carbon in rain is high) Phosphorus and other nutrients will be more inaccessible by plant	The use of solvents Phosphate Bacteria (<i>Aspergillus Niger</i>) – Idea from Hasanuddin University ((UNHAS)		
	Soil organic matter decline	<ul style="list-style-type: none"> Compost enriched by microbial Trichoderma, Mycorrhizae, <i>Aspergillus niger</i> ideas from UNHAS (Pest/disease control? E.g. Phytophthora?) Compost enriched with plants/ green manuring e.g. <i>Sesbania rostrata</i>, other? – Idea from: Thailand and India) Liquid Organic Fertilizer (LOF) enriched with Trichoderma – (Idea from: Makassar) Directly Treatment of green manure e.g. <i>Sesbania rostrata</i>, for example?, in rice field (Thailand and India) Vermicompost – (Idea from Philippine, Jogja and India) <i>Azolla</i> sp for nitrogen fertilizer in rice plants (Idea from: BFDW and India and UNHAS) A laboratory for analyze soil, compost, and water (Idea from: India) 	<ul style="list-style-type: none"> Compost enriched microbe (Trichoderma, Mycorrhizae, <i>Aspergillus niger</i>) in all assisting areas (dosage, treatment, and material are measurable) Compost kitchen waste residue Compost enriched with <i>Sesbania rostrata</i> to all assisted villages Liquid Organic Fertilizer (LOF) enriched with trichoderma in all assisted village Using acid tolerant rice varieties Vermicompost (Casting) <i>Azola</i> for nitrogen fertilizer in rice field Comparison between LOF GT formula and LOF from other parties Provide a laboratory for analyze soil, compost, and water 	<ul style="list-style-type: none"> To indentify the type of compost suitable for paddy, coffee, cocoa and vegetables (yields rise) There are books compost formula Reduce production costs GT compost formulas have academic evidence Easy to get a laboratory analysis with low cost
	Poisoning by Aluminum (Al) and Ferrum (Fe) high. Lack of Calcium (Ca)	Extra Calcium to increasing Soil pH by administering Skin Flour of snail (Idea from: Kondoran)	Need additional information whether all activities in number b. are able to answer the toxicity of Al and Fe. OK if soil is above pH 4.5 add chalk?	
	Perhaps there are plants that are extinct	Endemik seed promoting	<ul style="list-style-type: none"> Local paddy Demplot Establishing seed bank for local varieties (paddy and vegetable) 	
2	Longer dry season (Drought)			
a)	The rice yield decreased (rain fed)	<ul style="list-style-type: none"> Drought resistant varieties for upland rice (Idea from: Indonesian Seed Institute and India) Seed priming with local varieties (Idea from: UNHAS) Planting timing (Research in lowland rice in Sidrap and UNHAS research) Planting time (Season Calendar) Utilization of Meteorology Climatology and Geophysics Council (BMKG) forecast at farmers' level Idea from: SLI Module for rice) Fertilizing with application of microorganisms (Mycorrhiza, Trichoderma, Azotobacter, 	<ul style="list-style-type: none"> Planting Rice Drought resistant varieties for upland rice in 6 villages Seed priming will be tried in 6 villages with more scientific treatments Looking for a local rice varieties with drought resistance beside black rice Comparing between local varieties and rice from Indonesia Seed Institution The timing of planting (Season Calendar) to take advantage of the weather forecast from BMKG at the farmers' level 	<p>Rice production remains in drought</p> <p>idem</p> <p>New module</p>

No	20 Impacts of Climate Change on Agriculture	New Ideas for Adaptation / Best Practice (from where?)	Activities in the target Village	Output Expected
		Asperillum) on dry land conditions (Research from UNHAS and IPB)		
b)	See: 1.a, 1.b, 1.c.	Planting alternative staple food such as various of Taro (<i>Colocasia esculenta</i>) (Idea from: Toraja Utara)	Planting alternative staple food such as various of Taro (<i>Colocasia esculenta</i>) with new treatments such as with compost, planting method and planting time suitable plant species	Farmers have a food reserve if the rice harvest failed.
c)	The harvest of chili decreases	<ul style="list-style-type: none"> • Drip Irrigation (Idea from: UNHAS) • Early pruning technique (Idea from: UNHAS) • Using mulch from organic material (Idea from GT and UNHAS) 	<ul style="list-style-type: none"> • Drip Irrigation will be tried at Tallang Sura, La'bo, Batu Sura', To Pao, and Bua Tarrung • Cultivations and Early pruning technique • Using mulch from organic material 	<ul style="list-style-type: none"> • Reduce women working hours for watering vegetable / chili and water saving • Chili and vegetable production are stable
d)	Vegetable production are decreasing	<ul style="list-style-type: none"> • Drip Irrigation (Idea from: UNHAS) • Using mulch from organic material (Idea from GT and UNHAS) 	<ul style="list-style-type: none"> • Drip Irrigation will be tried at Tallang Sura, Pokkarondang, Batu Sura', To Pao, and Bua Tarrung • Using mulch from organic material 	
e)	Cacao production decreasing	<ul style="list-style-type: none"> - Plantation sanitation (Idea: research by Prof Laode-UNHAS) - Plant rehabilitation 	<p>Need information on how far the cocoa plant fits in Toraja.</p> <p>Offered to institutions in Germany to help overcome the Cocoa disease.</p>	
f)	Powdery mildew and pest whitleflies in chilli and tomato crops and string beans are increased	Botanical pesticides (Idea from: research of Prof. Sylvia Sjam-UNHAS) –GT Pesticides formulas from GT and have been application by farmers (tea + tobacco + garlic)	Using Botanical pesticides formula from UNHAS and GT	<ul style="list-style-type: none"> • Overcoming the Powdery mildew and whitleflies in chilli and tomato crops • Increasing production • There are books with the right formula for each commodity • GT pesticides formulas have academic evidence
g)	Corn production are decreasing or without production	<ul style="list-style-type: none"> • Drought-tolerant maize varieties (Idea from: Balitsereal) • Suitable place and good timing for planting 		
h)	Viability and vigoritas (germination power) are decreases	<ul style="list-style-type: none"> • Seed storage technique (Idea from: Balitsereal and India) • Seed treatment (Idea from: UNHAS) 	<ul style="list-style-type: none"> • Establishing seed bank in Kondoran and in villages • Comparison seed storage in Balisereal and in India • Seed treatment 	<p>Seed stock is always available</p> <p>Keeping local seed for not extinct</p> <p>Extend viability (endurance seed)</p>
i)	Lack of livestock (pig) forage (high cost)	<p>Alternative feed forage (a grass)</p> <p>Hibiscus leaf as pig forage to change the sweet potato leaf (Idea from: GT)</p>	<p>Using Hibiscus leaf as pig forage to change the sweet potato leaf and see how far it is worked (with scientific analyze)</p> <p>Provide information on nutrition content of each pig forage</p>	<ul style="list-style-type: none"> • The working hours of women decreased for feeding their pigs • Availability pigs forage in the dry season is guaranteed • Reducing production costs
j)	ND disease of poultry are increasing	<ul style="list-style-type: none"> • Plant a special species as a barrier to prevent virus attacks (Idea from: Farmers in Toraja) • Vaccination 		
3	Changing rainfall patterns (extreme rain) Land slide disasters increasing	<ul style="list-style-type: none"> • Vegetative Terracing with using <i>Sesbania rostrata</i> or <i>Mucuna</i> (Idea from: GT and UNHAS) • Planting trees (Idea from GT) • Planting vetiver –(Idea from LHP) 	<ul style="list-style-type: none"> • Vegetative Terracing with using <i>Sesbania rostrata</i> or <i>Mucuna</i> • Planting vetiver in open lands • System of row crops 	<p>Reducing erosion and landslide</p> <p>Reducing runoff</p>

No	Impacts of Climate Change on Agriculture	New Ideas for Adaptation / Best Practice (from where?)	Activities in the target Village	Output Expected
		<ul style="list-style-type: none"> System of row crops (Idea from: UNHAS) IFS (Integrated Farming System) especially for prevent land slide 	<ul style="list-style-type: none"> Reforestation combined with food crops (will be looking for the kind of commodity) and production animal feed (the German Institution is expected to look for a best practice) IFS (Integrated Farming System) especially for prevent land slide (Note: UNHAS or Germany Institution need to looking for a reference) 	
	Increased soil erosion in productive land (topsoil)	<ul style="list-style-type: none"> Mulching (Idea from: UNHAS) System of row crops (Idea from: UNHAS) 	<ul style="list-style-type: none"> Mulching o vegetable garden System of row crops (slopes crossing) Need more innovation to prevent erosion 	Reduce erosion
	Puddles plants in Kondoran, Labo 'and Pokkarondang. (incidental only)	<ul style="list-style-type: none"> Repairing drainages Puddle resistant varieties (Idea from India) 		
	Post-harvest disrupted for rice, cocoa, corn, etc.	Drier closet (Idea from India and LHP)	Drier closet (modification of the solar drier in LHP)	Preventing damage in the drying process
	Increased rice crop diseases (stem rot, bacterial wilt, fungi, Tunro viruses)	<ul style="list-style-type: none"> Setting the time for planting (season Calendar) which implies the cropping pattern (Idea from India, GT, CCROM, and UNHAS) Setting the time for planting (season Calendar) with using BMKG forecast at farmers' level (Idea from SLI Module) Planting disease-resistant varieties (local varieties: black rice, red rice) - proof of farmers in Toraja. 	<ul style="list-style-type: none"> Create a local planting season Translating the language of BMKG / scientific to practical language that is easily understood by farmers in Climate Field School for rice in 5 sub centers Using local varieties in the rice research 	Production of rice is stable during extreme rain
	Chili and vegetable diseases increases (stem rot, fungus, yellow virus)	<ul style="list-style-type: none"> Organic pesticide – UNHAS, Kondoran (bawang putih) Organic pesticide (Idea from GT and UNHAS) 	<ul style="list-style-type: none"> Organic pesticides were able to overcome the emerging diseases during the extremes rainy season 	
	Cocoa diseases (cacao fruit borer, stem borer, etc.).	<ul style="list-style-type: none"> Condomisation (Idea from: Plantation Office of South Sulawesi) Side grafting and grafting (Idea from Soppeng, Mamuju, and Luwu) Sanitation and pruning (Idea from UNHAS) 	<ul style="list-style-type: none"> Condomisation Side grafting and grafting Sanitation and pruning 	<ul style="list-style-type: none"> Preventing the spread of disease Develop disease-resistant cocoa
	Horticultural fertilization decreased	<ul style="list-style-type: none"> Greenhouse –(Idea from GT) Adding micro nutrient (Ca - Calcium and Bo-Boron) in the soil (Ideas from UNHAS) 	None	
4	Higher temperature (assumption) - Validation data from BMKG Pongtiku and Global weather The number and types of pests increase			
5	Tornado and strong wind are increased Paddy fall so that the harvest damaged Horticultural fertilization failure			
6)	From all (1-6) Food prices are increasing and food security threatened	Planting alternative staple food such as various of Taro (<i>Colocasia esculenta</i>) (Idea from: Toraja Utara)	Planting alternative staple food such as various of Taro (<i>Colocasia esculenta</i>) with new treatments such as with compost, planting method and planting time suitable plant species	Farmers have a food reserve if the rice harvest failed.

No	Impacts of Climate Change on Agriculture	New Ideas for Adaptation / Best Practice (from where?)	Activities in the target Village	Output Expected
	Farmers income are decreasing	Farmers group produce certification paddy seed (Idea from India and UNHAS)	<ul style="list-style-type: none"> strengthen existing track Production Marketing through Motivator program Farmers group produce certification black paddy seed Lobbying to Agriculture office to buy the seed and distribute for free to all farmers in Tana Toraja Introduce snowberry (need more information) 	
Notes:	UNHAS = Universitas Hasanuddin GT = Gereja Toraja (NGO) CCROM = previous project		BMKG = Weather Station LHP = Light House Project (Previous Project) IPB = Institut Pertanian Bogor (Agricultural Bogor University)	

4.3. Proposing for actions

Surmaini et al [2] recommended activities consisting of mitigation and adaptation efforts. Among the mitigation efforts are the use of low emission varieties and fertilizers, non-tillage technology (also in [24]) and intermittent irrigation. While adaptation measures are adjustment on planting pattern and time (also in [24–26]), use of superior and resistant varieties, rain harvest technology and irrigation technology. Learning from research by [18], farmers are also unaware about superior varieties for withstanding unfavourable environmental atmosphere due to climate change.

Bringing all those lessons from elsewhere into Torajan farmers' concerns increase their curiosity for trying and experimenting for the best solutions for the climatic related challenges in their area. With the guidance from the university, the next phase of workshop and FGD is for the formulation of field experiment. Figure 2 shows some parts of brainstorming process which involve farmers in formulating the field experiment.

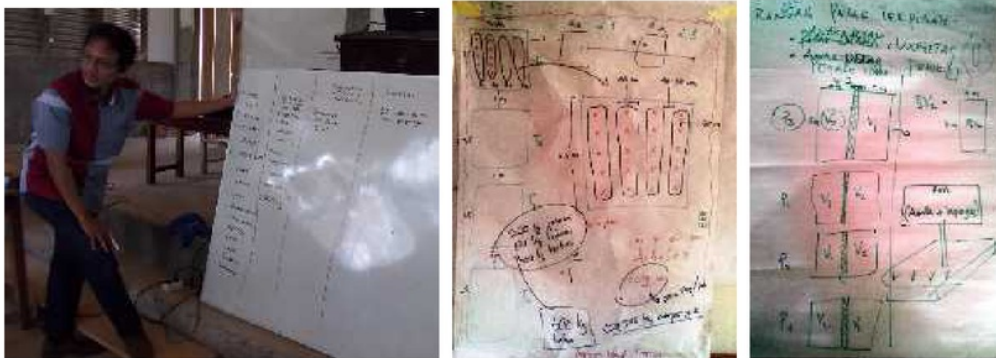


Figure 2. FGD for formulating field experiment that is scientifically manageable for farmers

Turning a farmer into a farmer researcher requires ability to develop questions of things they bewildered on or off-farms. They should be able to choose among options in an absence of manual or instructions. It is only possible after testing the options in experiment, and the experiment is valid only when it follows principle of experimental design [27]

Therefore, one important principle for the proposed research and experiment activity is that it should be scientific, yet practicable and manageable by farmers. Given that when the project is over, the farmers are still capable of handling similar experiment activity in the future. Also important that the anticipation strategy as well as the projected adaptation program need to be supported by innovative and adaptive technology [1].

5. Conclusion

Climate change has become a disaster to agriculture and farmers in general. However, there have been many efforts for adaptive agriculture which farmers can learn and implement. In order to make the adaptation program successful, the farmers involvement at all stages is important, from understanding the problem, thinking for possible solution and ever formulating and designing strategies for adaptation. Farmers in Toraja has demonstrated their eagerness and willingness to get involved in activities for climate change mitigation and adaptation efforts. Their participation has been very significant, as seen in their capabilities of identifying problems as well as proposing solutions.

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