TECHNOLOGY NEEDS ASSESSMENT (TNA) FOR CLIMATE CHANGE MITIGATION IN AGRICULTURE SECTOR: CRITERIA, PRIORITIZING AND BARRIERS

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ABSTRACT

Mitigation action in agriculture sector is crucial since it contributes to greenhouse gas emission, yet technologies need for have not been assessed. The technology needs assessment for the agriculture sector cover paddy field, perennial crops, peat soil, and livestock. The concern of the assessment is categorized into technology options, priority/key technology, barriers, and modalities. Selected technologies are based on criteria and priority options of technology needs. Data and information have been collected from related agencies, center, institutes and other relevant sources as well as through a workshop. Technology selection process for mitigation considered general criteria of reducing GHG emissions from crops and livestock, promoting resource conservation, promoting sustainable biodiversity, promoting green energy, sustaining food security, and promoting energy alternative; and specific criteria of promoting local technology for mitigation, sustaining site-specific germ plasms, promoting simple and cheap technology for poor farmers, promoting less emission crop varieties, substituting chemical with organic fertilizers/compost, and reduce CH_4 *emissions. Those criteria are scored into 4 classes, i.e. high value/ high relevant/high impact (score: 5), Medium value/relevant/med impact (score: 3); Low value/less relevant/less impact (score: 1); nil – not relevant/no impact (score: 0). The assessment has come up with the results that priority technologies needed for mitigation are (a) low methane emitter crops varieties, appropriate fertilizing, no tillage, and intermittent irrigation for paddy fields, (b) appropriate slash and burn and bio-fuel for perennial crops, (c) composting manure and biogas production for livestock, and (d) overcoming slash and burn, avoiding over drain and maintaining soil moisture for peat soils.*

Key words: GHG emission; Mitigation; Technology Need Assessment (TNA); Criteria; Barriers for mitigation; Agriculture sector

ABSTRAK

Upaya mitigasi di sektor pertanian menjadi sangat penting karena sektor ini berkontribusi terhadap munculnya emisi gas rumah kaca (GRK), namun demikian kajian terhadap kebutuhan teknologi untuk mitigasi belum dilakukan. Kajian difokuskan pada seleksi teknologi, kendala dan peluang untuk mengatasi masalah. Seleksi teknologi didasarkan pada criteria dan opsi teknologi yang diperlukan. Data dan informasi dikumpulkan dari berbagai lembaga baik badan, pusat dan lembaga-lembaga terkait lainnya serta melalui lokakarya yang melibatkan para pemangku kepentingan. Seleksi teknologi untuk mitigasi mempertimbangkan criteria umum yang meliputi pengurangan emisi GRK dari tanaman dan ternak, konservasi sumberdaya, untuk keberlanjutan keanekaragaman hayati, mengangkat isu energi hijau, keberlanjutan keamanan pangan, dan mengangkat isu energi alternatif; dan spesifik criteria yang meliputi memprioritaskan teknologi *lokal untuk mitigasi, keberlanjutan plasma nutfah spesifik lokasi, memprioritaskan teknologi yang murah untuk petani miskin, introduksi varietas tanaman yang rendah emisi, mengganti sebagian pupuk kimia dengan pupuk organik, serta mengurangi emisi gas metana (CH_4). Kriteria tersebut diskor kedalam 4 kelas, yaitu nilai tinggi/relevansi tinggi/sangat berdampak (skor 5), nilai sedang/relevan/berdampak sedang (skor: 3); nilai rendah/kurang relevan/kurang berdampak (skor: 1); dan tidak relevan/tidak berdampak (skor: 0). Hasil kjian menunjukkan bahwa prioritas teknologi yang dibutuhkan untuk mitigasi : (a) untuk lahan sawah: varietas tanaman dengan emisi rendah, pemupukan yang tepat, tanpa olah tanah/olah tanah minimum, dan irigasi berselang, (b) untuk tanaman tahunan: teknologi tebang baker yang tepat dan biofuel, (c) untuk peternakan: teknologi pengomposan dan biogas, dan (d) untuk lahan gambut:: menghindari tebang bakar, menghindari drainasi yang berlebihan dan menjaga kelembaban tanah.*

Kata kunci : Emisi GRK; Mitigasi; Kajian Kebutuhan Teknologi (KKT); Kriteria; Hambatan Mitigasi; Sektor pertanian

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I. INTRODUCTION

The agriculture sector contributes significantly to global carbon emissions from diverse sources such as product and machinery manufacture, transport of materials and direct and indirect soil greenhouse gas emissions[1)] and agricultural soils have been identified as one of the main GHG source[2)], yet the inventory of GHG emission in agriculture sector, compared to that in the energy sector, is limited. In 2000, inventories for estimating GHG emission from agriculture have noted that the agriculture sector has contributed about 14% of the total GHG emission[3)] as seen in Figure 1. According to Smith[4)], agriculture accounts for an estimated emission of 5.1 to 6.1 gigatonnes (Gt) carbon dioxide (CO_2)eq/yr in 2005 (10-12 % of total global anthropogenic emissions of GHGs).

In Indonesia, the inventory of GHG emissions in 1990, showed that rice field was the highest GHG contributor among the major sources in the agriculture sector. As high as 3,649.2 Gg of CH_4 has been emitted from rice fields, the burning of crop residues and livestock; 25.5 Gg of N_2O from the application of fertilizers and the burning of crop residues; 564.4 Gg of CO from burning crop residues; and 22.8 Gg of NOx from burning crop residues[5)]. These data are assumed to have increased over the past few years. The World Resources Institute[6)] reported that various sources of emission of non-CO_2 have developed from the agriculture sector. Fertilizers contributed as high as 38% of N_2O, livestock as high as 31% of CH_4, rice as high as 11% of CH_4, manure 7% of CH_4 and N_2O, and other agriculture sub-sectors 13% of CH_4 and N_2O (Figure 2). It has also been found that emissions from rice fields are influenced by rice varieties. It was reported that emissions from the Cisadane rice variety was 94.8 kg/ha, while that from the Way Apo variety was 58.9 kg/ha[7)].

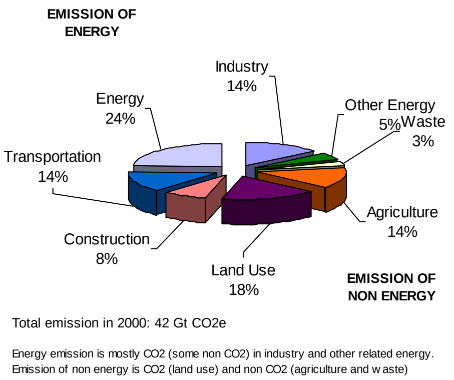

Figure 1. GHG emission from various sector in 2000[3)]

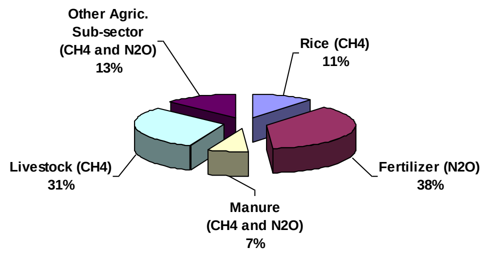

Figure 2. Emission sources of non CO_2 from agriculture[6)]

The animal-husbandry industry is also contributing to GHGs emission, especially CH_4 and CO_2. Globally, it is reported that about 300 million tons of methane gas are released to the atmosphere annually, where about 30% comes from ruminant. The methane gas in animals is generated specifically from the food digestion system and the metabolism. In a farm animal, the internal digestion system together with methanogenic bacteria, helps the particular biochemical process and creates methane gas. From their study in extensively and intensively managed diary producers in a dry land area of Inner Mongolia, China, Wilkes and Wang[8)] reported that average emissions across the 9 farm enterprises were 14.32 kg CO_2e per kg milk produced, with a range from 2.53 kg CO_2e per kg milk to 57.6 kg CO_2e per kg milk. For the two highest emitters, the average was 39.5 kg CO_2e per kg milk.

From the perennial crops point of view, waste of the oil palm industry is also a potential of emission sources. Waste of this industry could be classified into two kinds: waste-water from the factory and solid waste from the field and factory. Waste-water has to be treated before being discharged into any body of usable water, while the solid waste consists of fruit peelings, leaves, trunks, fibers, shells, and stumps. The total amount of the oil palm industry's solid waste in Indonesia was around 18 million ton in 2005 and the oil palm wastewater was around 8 million ton. Potential of GHGs emissions from the oil palm industrial waste is mainly the CH_4 emission.

An estimation of the mitigation-potential from rice field has been made, by introducing a rice variety which has relatively lower potential emissions. The mitigation potential, through technology, is based on the emission-reduction and the cost of mitigation. If Way Apo (lower emission potential) rice variety is introduced to change the Cisadane variety, the emission of CH_4 will be reduced by up to 37.8%[7)], while the cost of mitigation was as high as 361,200 rupiahs per ha or about US$ 40/ha.

Another approach, to mitigate emissions through soil and water management, may also be implemented. For rice-field management, the rice crop is often submerged under some 20 cm of standing water, with limited drainage during the irrigation cycle. This reduces land area and stimulates high CH_4 emissions. Intermittent irrigation, by which the water is drained during the irrigation cycle, eliminates the reduction potential and finally reduces the CH_4 emission by about 50-60%[9)]. Cost for implementation of this type of irrigation is about US$ 200-300 per ha if irrigation channels and gates already exist, and about US$ 400-500 per ha if there are none.

Mitigation strategies can be implemented by considering local farming-specific. Intermittent irrigation for rice field is one of the strategies of land and water management that may reduce CH_4 emission. In many cases, farmers prefer to maintain standing water in the field as high as 20 cm without any consideration to drain it, after a period of 2-4 weeks. This leads to a condition that a rice field produces much CH_4. Whereas, intermittent irrigation provides an aerobic condition where oxidation processes occur. Introducing crop varieties is also an option to be presented to farmers. Crop selection and breeding seem to be alternatives to less emission crops varieties. Research institutes such as the Indonesian Center for Rice Research are becoming very important to provide new rice varieties with less emission. Developing rain-fed rice may also be possible to reduce CH_4 emissions, and intermittent irrigation can reduce by 50-60% of CH4 emissions from rice fields[9)]. Integrated crops-livestock management is another strategy which may contribute to reduced emissions. Manure should be converted into compost for fertilizer and fresh manure, which may not emit greenhouse gases such as CH_4 can also be converted into bio-gas, to produce energy for electricity, cooking and other proposes which may help farmers.

The objectives of the study were to identify the potential criteria for mitigation technologies selection, to assess the mitigation technology options for rice fields, perennial crops, livestock and peat soils and to some extend to identify barriers and policy-needs for mitigation action.

II. MATERIALS AND METHODS

The technology need assessment (TNA) for mitigation has been conducted from June 2007 to April 2008 based on communication and discussion as well as workshop involving various stakeholders. The assessment was addressed for rice field, perennial crops, livestock and peat soils. The concern of the assessment is categorized into technology options, priority/key technology, barriers, and modalities. Selected technologies are based on criteria and priority options of technology needs. Technology needs are country-specific, economically profitable, socially acceptable, and environmentally friendly.

2.1. Identification of Technology Criteria for Assessment

Criteria used for technology selection includes general and sector-specific which are used to identify technologies for mitigation. Technologies for mitigation are selected based on their potential reduction of GHG emissions. The specific criteria of the sector are based on the site and users of a particular mitigation technology. The criteria for selecting mitigation technologies for TNA of the agricultural sector are based on three considerations which are:

1) The mitigation technologies should contribute to three important goals of realizing food security, increase farmers' income, and agribusiness development. The mitigation technologies should be economically beneficial, socially acceptable, and environmentally benign.
2) The technologies should address climate change mitigation which reduces GHG emissions (e.g. low emission of crops varieties, composting, etc.) and enhance carbon sink.
3) The contribution to market potential which can involve an analysis of capital and operating costs relative to alternatives, the commercial availability of the technology, and the technology's replicability, applicability, adaptability, and potential scale of utilization.

Technology selection process for mitigation was based on general and specific criteria. The general criteria used in the selection process are:

- Reducing GHG emissions (RGHG),
- Promoting resource conservation (RC),
- Promoting sustainable biodiversity (SB),
- Sustaining food security (FS),
- Promoting energy alternative (EA),

The specific criteria are:

- Promoting local technology for mitigation (LW),
- Sustaining site-specific germ plasms (GP),
- Promoting simple and cheap technology for poor farmers (SCT),
- Substituting chemical with organic fertilizers/compost (SOF),
- Reduce CH_4 emissions (RCHE).

The criteria for technologies selection are based on the magnitude of the impact of technology to climate change mitigation. Assuming that the magnitude of reducing GHG emission is different in function of technology, the criteria used for selection are based on relevancy or the magnitude of the impact to reduce GHG emission. Based on those criteria, technologies were, then, evaluated with scoring into 4 classes, i.e. H: High value/high relevant/high impact (score: 5), M: Medium value/relevant/med impact (score: 3), the impact to reduce GHG emission is in between high and low; L: Low value/less relevant/less impact (score: 1); and NR: nil – not relevant/no impact (score: 0). Technology for mitigation action was prioritized based on the total point of score of the entire general and specific criteria used in the evaluation. Total point of score was calculated by summing total point of score of general and specific criteria for each evaluated technology. Barriers for mitigation actions have been identified during communication and discussion among the stakeholders as well as from the workshops. Based on the identified barriers policy-needs have been formulated.

2.2. Prioritization of Key Technologies

The selected technologies for mitigation were ranked for prioritizing key technologies for each agricultural sub-sector including rice field, perennial crops, livestock and peat soils. Prioritizing key technologies were based on their potential to mitigate climate change and possibility for farmers to apply and those are reflected to the total point in the scoring process. Those having high total point were selected as priority technology.

2.3. Identification of Barrier and Policy-needs

Identification of barriers in mitigation actions was based on several criteria including simplicity of technology to apply, cost for mitigation actions, the state of capacity of farmers, the state of farmer's knowledge and experiences in mitigation action, and benefit to apply technologies for mitigation. Policy needs are formulated with regard on the identified barriers.

III. RESULTS AND DISCUSSION

3.1. Potential Criteria

Considering the general and specific criteria, respective reducing GHG emission (RGHG) and reducing CH_4 emission (RCHE) are the most relevant criteria should be used in the mitigation technologies selection process (Figure 3 and 4). Promoting energy alternative (EA) is also potential criteria to consider in the selection of technology for mitigation. This suggests that criteria used for technologies selection should not only consider the potential for reducing GHG emission but also other benefit gained from those technologies. For instance, the technology used for composting does not only mitigate manure to release methane (CH_4) but also resulting compost for fertilizing and ameliorating soil for increasing fertility. This is the reason why criteria to promote energy alternative (EA) appears to have relatively higher score. The criteria to substitute a major part of chemical fertilizer to organic fertilizer (SOF) are becoming important for livestock. Biogas production as an energy alternative may potentially be promoted to convert manure and not let it to emit GHG to the atmosphere.

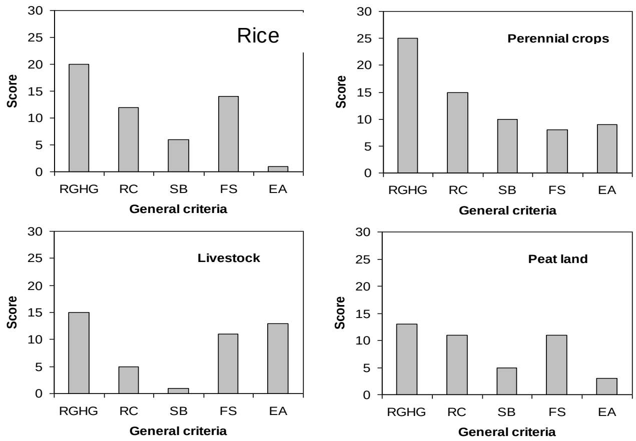

Figure 3. General criteria for mitigation technologies selection
RGHG: reducing GHG emission, RC: promoting resource conservation, SB: promoting sustainable biodiversity, FS: sustaining food security, EA: promoting energy alternative

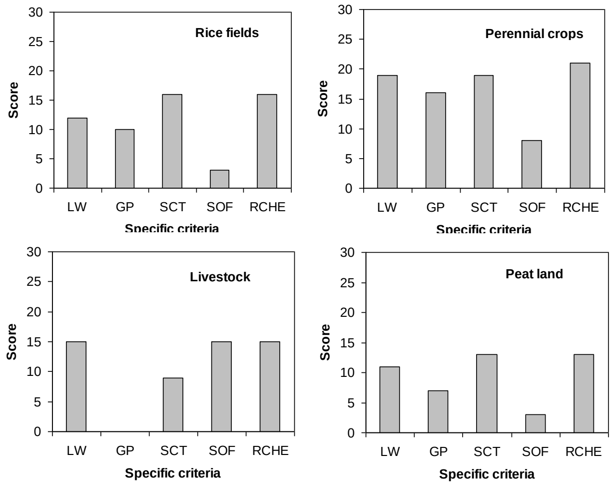

Figure 4. Specific criteria for mitigation technologies selection
LW: promoting local wisdom technology for mitigation, GP: sustaining site specific germ plasms, SCT: promoting simple and cheap technology for poor farmers, SOF: substituting chemical with organic fertilizers/compost, RCHE: reduce CH_4 emission

. Reducing CH_4 emission has relatively higher score especially for perennial crops and to some extend for rice fields. Technologies to mitigate climate change needs intervention of principles knowledge based on reducing GHG emission. It was also found that selected technologies should be simple and cheap (SCT) so that farmers may easily implement.

3.2. Priority Technologies

Technology selection process for mitigation using general and specific criteria has come up with the results that low methane emitter crops varieties and appropriate fertilizing are the two top mitigation technologies option for rice field, low methane emitter crops varieties and appropriate slash and burn for perennial crops, composting manure and biogas production for livestock and overcoming slash and burn and avoiding over drain for peat soils (Table 1 and 2).

Mitigation measures, through crop, management, with fertilizing and no tillage technology are potentially implemented by farmers, as a means of reducing GHG emissions from the agricultural sectors. Water management should also be considered, where intermittent irrigation, drainage to reduce CH_4 emissions and the introduction of rain-fed rice are priority technologies option. Mitigation may also be

Table 1. Technology selection process for mitigation using general criteria

List of Technology	General Criteria					TP
	RGHG	RC	SB	FS	EA	
A. Rice/Horticulture						
• Low methane emitter crops varieties	H	H	M	M	NR	16
• No tillage	H	L	L	M	NR	10
• Appropriate fertilizing	H	M	L	H	L	15
• Intermittent irrigation	H	M	L	M	NR	12
B. Perennial crops						
• Low methane emitter crops varieties	H	H	M	M	NR	16
• No tillage	H	L	L	L	NR	8
• Appropriate fertilizing	H	M	L	M	M	15
• Appropriate slash and burn	H	H	H	L	L	17
• Biofuel	H	L	NR	NR	H	9
C. Livestock						
• Composting manure	H	M	L	M	H	17
• Biogas production	H	L	NR	M	H	14
• Bio-urine production	H	L	NR	H	M	13
E. Peat land						
• Overcoming slash and burn	H	H	M	M	L	17
• Avoiding over drain	H	M	L	M	L	13
• Maintaining soil moisture	M	M	L	H	L	13

Reducing GHG emission (RGHG), promoting resource conservation (RC), promoting sustainable biodiversity (SB), sustaining food security (FS), promoting energy alternative (EA)

H: High value/ high relevant/high impact (score: 5), M: Medium value/relevant/med impact (score: 3); L: Low value/less relevant/less impact (score: 1); NR: nil – not relevant/no impact (score: 0),

TP: Total point

Table 2. Technology selection process for mitigation using specific criteria

List of Technology	Specific Criteria					TP
	LW	GP	SCT	SOF	RCHE	
A. Rice/Horticulture						
• Low methane emitter crops varieties	H	H	M	NR	H	18
• No tillage	M	L	H	NR	L	10
• Appropriate fertilizing	M	M	H	M	H	15
• Intermittent irrigation	L	L	M	NR	H	10
B. Perennial crops						
• Low methane emitter crops varieties	H	H	M	NR	H	18
• No tillage	M	M	H	NR	L	12
• Appropriate fertilizing	M	M	H	H	H	21
• Appropriate slash and burn	H	H	M	NR	H	18
• Biofuel	M	NR	M	M	H	14
C. Livestock						
• Composting manure	H	NR	M	H	H	18
• Biogas production	H	NR	M	H	H	18
• Bio-urine production	H	NR	M	H	H	18
E. Peat land						
• Overcoming slash and burn	H	H	M	M	H	21
• Avoiding over drain	M	L	H	NR	H	14
• Maintaining soil moisture	M	L	H	NR	M	12

Promoting local wisdom technology for mitigation (LW), sustaining site specific germ plasms (GP), promoting simple and cheap technology for poor farmers (SCT), substituting chemical with organic fertilizers/compost (SOF), reduce CH4 emission (RCHE)

introduced through biomass (manure) processing, as well as composting manure and converting it into biogas. Since peat soils are fragile, mitigation technologies need to be implemented in appropriate ways. Overcoming slash and burn, avoiding over drain and maintaining soil moisture are most appropriate technologies for mitigation in peat land areas.

Despite the low emitter crop varieties is a potential criterion, but it has to be carefully used by considering preference of farmer to use those varieties. Converting the use of Cisadane rice variety to Way Apo rice variety may reduce GHG emission, as it has been reported by Setyanto *et al.*[7)] that emissions from the Cisadane rice variety was 94.8 kg/ha, while that from the Way Apo variety was 58.9 kg/ha, but it should be considered in introducing that variety while farmer's preference is lower. Introducing rice variety with low emission and high farmer's preference is, off course, becoming most potential criteria for technology selection. The rice variety with those criteria is crucial to be produced through appropriate breeding process.

Prioritizing mitigation technology options should not consider single criteria as it has been mentioned in the previous discussion, but it should also be based on the economic, social and environmental benefits gained from those technologies implementation. As it has been found in the evaluation that composting manure is priority technology for mitigation in the livestock sub-sector, technically this technology option is able to reduce GHG emission, economically farmers may gained income from compost or reducing cost for chemical fertilizers, socially it is relatively easier to implement and the bed smelt of manure will not be disturbed the farmer's neighbor, and environmentally a bed smelt of manure can be overcome and the shelter keeps clean.

The priority of mitigation technologies of each sub-sector is presented in Table 3. The priority of mitigation technologies for rice fields are (a) low methane emitter crops varieties, (b) appropriate fertilizing, (c) no tillage, and (d) intermittent irrigation while for perennial crop are (a) appropriate Fertilizing, (b) low methane emitter crops varieties, (c) appropriate slash and burn, (d) bio-fuel, and (e) no tillage. For livestock sub-sector the priority technologies are (a) composting manure, (b) biogas production, and (c) bio-urine production while for peat soil are (a) overcoming slash and burn, (b) avoiding over drain and, (c) maintaining soil moisture.

Low emission crop varieties and appropriate fertilizing should be a key technologies for crops either food or perrenial crops. When those technologies are integrated with intermittent irrigation for food crop and slash and burn technology for perennial crops the impact to reduce GHG emission will be more significant. Composting and biogas development technologies are necessary for livestock sub-sector. To reduce GHG emission in peat land areas, water management covering drainage system and keeping water table in certain level is important to maintain soil moisture.

3.3. Barrier and Policy-needs

Various barriers in mitigation action have been identified in the assessment process, i.e. It takes time to produce low GHG emission crops varieties, Mitigation technologies are not widely known to farmer, cost of mitigation technology implementation is relatively high for farmers, limited knowledge of farmers, limited capital of farmers to implement mitigation technologies, and expected benefit and beneficiaries. Those barriers need appropriate policies to come up with suitable mitigation actions. The barriers and policy-needs for mitigation action are presented in Table 4.

Several mitigation activities have been conducted by various institutions, as a means of anticipating climate change. It is important - and must be realized - that integrated activities are urgent. Issues spanning many sectors (Agriculture, Energy, Health, Industry, Transportation, Forestry, Ocean, and Waste) must be identified, in order to prepare appropriate action programs on mitigation. Coordination among the institutions is required to implement comprehensively action programs.

Table 3. Technologies priority for mitigation to climate change

Agriculture sub-sector	Mitigation Technologies
Rice fields/ Horticulture	a. Low methane emitter crops varieties b. Appropriate fertilizing c. No tillage d. Intermittent irrigation
Perennial crops	a. Appropriate Fertilizing b. Low methane emitter crops varieties c. Appropriate slash and burn d. Bio-fuel e. No tillage
Livestock	a. Composting manure b. Biogas production c. Bio-urine production
Peat Land	a. Overcoming slash and burn b. Avoiding over drain c. Maintaining soil moisture

Table 4. Barriers assessment and policy needs for mitigation action in agriculture sector

Barriers	Policy needs
Implementation	
• It takes time to produce low GHG emission crops varieties	• Improvement of crops breeding
• Mitigation technologies are not widely known to farmers	• Need of fare distributed dissemination technology
• Cost of mitigation technology implementation is relatively high for farmers	• Select a simple and cheap mitigation technologies
• Limited knowledge of farmers in mitigation	• Improvement of training
• Limited capital of farmers to implement mitigation technologies	• Need government support on financing mitigation technology implementation
• Expected benefit and beneficiaries	• Introducing high economic values of commodities
Dissemination	
• Limited awareness of farmers	• Improvement of awareness
• Limited knowledge of extension workers working on climate change and mitigation	• Need special training and on job training
• Lack of proper information system for dissemination	• Need information technology
• Gap of linkage between researchers and extension workers	• Need an umbrella program of dissemination
Capacity Building	
• High cost of capacity building in mitigation	• Need government support in financing capacity building
• Limited knowledge of trainers	• Improvement of training of trainers (TOT)
• Lack of skilled professional in capacity building in mitigation	• Need special training
• Lack of personnel for introducing and implementing mitigation technologies	• Need recruitment of skilled professional personnel
• Gap of information technology for capacity building	• Improvement of information technology

IV. CONCLUSIONS

Identifying potential criteria for mitigation technologies selection is key factor for suitable assessment. Reducing GHG emission (general criteria) and reducing CH_4 emission (specific criteria) are the most relevant criteria for mitigation technologies selection process. Criteria used for technology selection is technically suitable and it should economically be profitable. The priority technologies for mitigation in the rice fields have been selected to be low methane emitter crops varieties, appropriate fertilizing, no tillage, and intermittent irrigation while for perennial crops are appropriate fertilizing, low methane emitter crops varieties, appropriate slash and burn, bio-fuel, and no tillage. Composting manure, biogas production and bio-urine production are the priority technologies mitigation for livestock while overcoming slash and burn, avoiding over drain, and maintaining soil moisture are for peat land areas. Barriers in mitigation action will include some consideration that It is time consume to produce low GHG emission crops varieties, mitigation technologies are not widely known to farmers, cost of mitigation technology implementation is relatively high for farmers, limited knowledge of farmers in mitigation, limited capital of farmers to implement mitigation technologies, and expected benefit and beneficiaries.

V. REFERENCES

[1]Jonathan Hillier, Cathy Hawes, Geoff Squire, Alex Hilton, Stuart Wale, and Pete Smith. 2009. The carbon footprints of food crop production. International Journal of Agricultural Sustainability 7(2) 2009, pages 107–118.

[2]Erandathie Lokupitiya and Keith Paustian, 2006. Agricultural Soil Greenhouse Gas Emissions: A Review of National Inventory Methods. J. Environ. Qual. 35:1413–1427

[3]Stern, N. 2006. The Stern Review on Economics of Climate Change. http://www.sternreview.org.uk

[4]Smith, P. 2007. Greenhouse gas mitigation in agriculture. http://www.eoearth.org/article/Greenhouse_gas_mitigation_in_agriculture#Emission_trends.