Considering the limitations of the highly productive arable land for supporting food security in Indonesia, development and optimization of degraded peatlands for agricultural expansion is an option, although this area is one of the primary sources of Green House Gas (GHG) emissions. Consequently, specific management strategies should be applied to reduce the emission and to serve future generations. Also, mitigation of climate change in the peatlands agriculture should also be given priority. This paper explores the existing farming action on climate change mitigation, and strategies of degraded peatlands management to mitigate climate change in terms of reducing GHG emission. Existing condition of mitigation action by farmers in their farming systems; rice, rubber and oil palm, were reviewed through a farm household survey. Then, development strategies for climate change mitigation through sustainable degraded peatlands management were discussed through Focus Group Discussion (FGD) and in-depth interview with experts from concerned research institutions and universities through morphological analysis. The finding of this research shows that farmer’s existing climate change mitigation actions pertain to land preparation, water management, and soil management in their farming system. Moreover, specific actions and strategies to mitigate climate change in the sustainable degraded peatlands management which were determined based on the most relevant variables under a given future condition consist of constructing canal blocking system, introducing technology for water and soil management, revitalizing agricultural extension institution as well as establishing fire brigade and improving farmer experience and knowledge on climate change.

Keywords: climate change; mitigation; sustainable; peatlands; agriculture

Introduction
Climate change is a change of climate which is caused directly or indirectly by human activity that alters the composition of the global atmosphere (UNFCC, 2011). Increased greenhouse gas (GHG) emission such as CO₂, CH₄, NO₂ and CFCs (chlorofluorocarbons), which promotes global warming, is the primary source of global climate change (IAARD, 2011). One of the main sources of GHG emissions is peatlands (Jaenicke et al., 2008). Peatlands is an important terrestrial carbon pool which stores about 39% of the world soil carbon even though peatlands area is only 3% of the Earth's surface. High Carbon stored in peatlands indicates a high potential contribution of these ecosystems to GHG emissions. Under natural conditions, carbon storage on peatlands is relatively stable (Hooijer et al., 2010) but if the physical conditions are interrupted, it accelerates the process of decomposition, so the carbon stored in the peat is emitted in the form of GHG emissions, primarily CO₂ (Agus and Subiksa, 2008; Hooijer et al., 2010). Furthermore, Dariah et al. (2013) stated that the process of carbon emissions and sequestration in peatlands occurred through land-use changes, emissions due to drainage of peat, peatlands forest fires and, runoff of dissolved organic carbon and particulate organic carbon.
Indonesia is one of the major contributors of tropical peatlands with almost 13% of the globally tropical peatlands area (Gumbricht et al., 2017). The peatlands sprawl in Papua, Sumatra and Kalimantan Islands. Originally all the lowland peatlands of western Indonesia were a forest; however, intensive land use, especially for the last twenty years, logging activities, conversion to plantations, and expansion of small-holder agriculture caused degraded peatlands (Silvius and Diemont, 2007). It is characterized by changing in physical, biological and chemical properties, leading to the decline of hydrological, production and ecological function of peatlands (Anshari et al., 2010). Agus et al. (2014) reported that only 56% of the total peatlands in Indonesia is still covered by forest, similarly, in Central Kalimantan Province, only 57% is categorized as pristine peatlands forest and the remaining is categorized as degraded peatlands (Wahyunto et al., 2013).

Moreover, Indonesia has received international criticism for the environmental impact caused by peatlands degradation, especially peat forest fire. During the 1997–1998 El Niño event, an estimated 10 million ha across Indonesia was burned, including 1.5 million ha of peat swamp forests (Barber and Schweithelm, 2000). About 810 to 2,470 million tonnes of carbon stored in Indonesian peatlands were lost during this period or equivalent to 14–40% of worldwide fossil carbon emission in that year (Page et al., 2002). Additionally, the average annual emissions from peatlands in Indonesia during 2000–2006 was estimated approximately 903 million tonnes CO₂ year⁻¹ (Dariah et al., 2011), and recently Miettinen et al. (2017) estimated that Indonesia peatlands (Sumatra and Kalimantan) emitted 119.7 Million tonne C yr⁻¹ in 2015.

However, in line with the population explosion, land availability is becoming an important issue in the future. Considering the limitations of the highly productive arable land, development and optimization of peatlands for agricultural expansion is an option. But, specific management strategies should be applied to ensure the sustainability of peatlands agriculture as well as mitigation of GHG emission. Those strategies should emphasize the economic sustainability of production systems, conservation of peat layer, and minimize the negative impact on the environment, especially GHG emissions. Also, mitigation of climate change in the peatlands agriculture should also be given priority because while agriculture is affected by climate change, it is also a major source of GHG emission. Mitigation is defined as "technological change and substitution that reduce resource inputs and emissions per unit of output" (IPCC, 2007). Modification of current management practices on agriculture is a way to mitigate GHG emission. Wise use approach should be done to minimize the impact on CO₂ emission and sustains its potential to service the future generation. Furthermore, strategy options for mitigating climate change, including actions of the existing farmers’, should be identified. However, because mitigation of climate change is cross-sectoral, and cross-scale (local/national/international), effective coordination and synergy among various parties are needed.

This paper aims to identify the existing farming action which is related to climate change mitigation, and strategies to mitigate climate change in term of reducing GHG emission through sustainable management of degraded peatlands.

**Methodology**

This research was conducted in Central Kalimantan and focused on Kapuas and Pulang Pisau districts of Indonesia. In the study area, there are three farming systems practiced in the peatlands; they are rice, rubber and oil palm. Existing farmer actions related to climate change mitigation action by farmers in their farming system were reviewed through a farm household questionnaire. Selection of farmer household for questionnaire structured interview in the study site was done by stratified random sampling technique. The farmer households were classified into (1) farmer household with food crop farming system (rice); (2) farmer household with plantation farming system (oil palm) and (3) farmer household with plantation farming system (rubber plantation). A total of 220 farmers were interviewed in those three farming systems; rice, rubber and oil palm. Data collected from farmer household survey were analyzed using descriptive statistics.

Focus Group Discussion which is attended by 50 participants who have a significant role on the peatlands farming system (researchers, district agency staffs of food crops, plantation and food security, agriculture extension services, and farmers) was conducted to identify the main variables related to climate change mitigation. Based on the FGD, infrastructure, technology and institutional as well as farmers’ knowledge and experiences in climate change are predicted as the main variables or key driving variable for mitigation of climate change. Further exploration of key driving variables was done to determine possible conditions for the next 25 years (according to the time range). Three experts from research institutes and universities who have expertise in peatland farming system, climate change and policy analysis were chosen as respondents for an in-depth interview to discuss the circumstances that may happen in the future. From the expected future conditions of the key driving variable, scenarios that may occur in the degraded peatlands can be determined (Godet and Roubelat, 1996; Godet, 1994; Godet, 2010). Those scenarios were formulated into three clusters: (1) Conservative-pessimistic which is characterized by less improvement in the existing
Results and Discussion

Farmer’s existing practices on mitigation of climate change in the peatlands farming system

Based on the household survey, only 53.4% of farmer respondents understood about GHG emission in the peatlands, even though they have long experience in the peatlands farming system. In term of GHG emission, 67%, 48.75%, 41.67% of farmers in rice, oil palm and rubber farming system, respectively were familiar with GHG (Figure 1).

Although not all farmer understood the GHG emission in peatlands farming system, most farmers in the study area had already left their habit of slash and burn method in land preparation. They now use herbicide application followed by manual land tillage for the land preparation (Figure 2). In this case, they have indirectly mitigated climate change in their farming.

Most of farmers in rice and oil palm farming systems used fertilizer to improve soil fertility, while only 50% of farmers in the rubber farming system used fertilizer (Figure 3). In addition to using fertilizer, 53% of rice farmer applied ameliorant to the soil for improving the physical, chemical and biological properties of soil. Ameliorant application is another GHG mitigation action which is done by farmers especially in rice farming since Sabiham (2010) stated that application of ameliorant for rice cultivation using mineral soil and basic slag could reduce CO$_2$ emission.

Another mitigation action which is done by farmers is water management. The study found that only 37.5%, 40% and 45% of farmers in rice, oil palm and rubber farming systems, respectively carried out water management in their farming system (Figure 4). Based on the interview, farmers implemented water management in their farming system are intended to remove excess water, create an unsaturated condition for plant root respiration, and wash most organic acid out the soil. This action will also create hydrodynamic equilibrium condition between farmland and the surrounding area to prevent a fire risk.

Strategies of mitigation of CO$_2$ emission through sustainable degraded peatlands agriculture

Expected future condition in three different scenario based on the in-depth interview with expert are summarized in Table 1.
Figure 2: Existing land preparation methods.

Figure 3: Existing soil management practices.

Figure 4: Existing water management practices.
Strategies for mitigation of CO$_2$ emission through sustainable degraded peatlands agriculture are envisaged based on the analysis of key driving variables and scenario development. Those strategies consist of constructing a canal blocking system, introducing technology for water and soil management, revitalizing agricultural extension institution as well as establishing fire brigade and improving farmer experience and knowledge on climate change.

**Constructing canal blocking system**

Construction of canals blocking especially in the existing main irrigation channels is expected to prevent peatlands drainage. In the degraded peatlands management, restoration of hydrology (rewetting) has to be essentially done for raising the groundwater level to the peat surface which leads to reduced CO$_2$ flux due to low decomposition rate and protecting peat C stock (Jauhiainen et al., 2016). Moreover, blocking these canals for construction of a small dam is a promising way to mitigate climate change in term of reducing CO$_2$ emission as much as 1.4–1.6 million tonnes year$^{-1}$ could be achieved by rewetting 590 km$^2$ of drained peatlands through dam construction.

Based on the FGD, this mitigation action was also intended to prevent peat fire. Canal blocking will create a wet condition in the surrounding area which able to reduce extreme drying of peat in the dry season since dry peat is susceptible to fire.

**Introducing innovation technology for water and soil management**

Based on the household survey, only 37.5%, 40% and 45% of farmers in rice, oil palm and rubber farming systems, respectively carry out water management in their farming system, therefore, introducing innovative technology is essential for improving mitigation of climate change action. Based on the expert judgment, water and soil management technology is important in mitigating climate change. A combination of a one-way flow system and blocking system method is one of the innovative technology in peatlands farming.

### Table 1: Expected future condition and scenario formulation based on expert judgment.

| Variables                                      | Scenario I progressive-optimistic (Cluster A) | Scenario II moderate-optimistic (Cluster B) | Scenario III conservative-pessimistic (Cluster C) |
|-----------------------------------------------|---------------------------------------------|--------------------------------------------|--------------------------------------------------|
| Infrastructure                                |                                             |                                            |                                                  |
| • Construction of canal blocking for rewetting degraded peatlands area | 100% of area                               | 25%                                        | 0%                                               |
| Technology                                    |                                             |                                            |                                                  |
| • Availability and accessibility of technology for climate change mitigation on peatlands (water and soil management) | All available and accessed easily by farmers | All are available but farmers still have difficulties to access | Not available                                   |
| Institutional                                 |                                             |                                            |                                                  |
| • Availability and support of institutions related to for climate change mitigation on peatlands farming (agricultural extension and fire brigade) | The institutes are available and fully support farmers' activities | The institutes are available but not fully support farmers | The institutes are not available |
| Farmer's experience in sustainable peatland agriculture |                                             |                                            |                                                  |
| • Farmers' knowledge on climate change mitigation on peatlands agriculture | All farmers understand sustainable peatlands agriculture and fully adopt and apply it | All farmers understand sustainable peatlands agriculture but not totally adopted | Not all farmers (<50%) understand sustainable peatlands agriculture and not adopted |
system. This method is intended to maintain a moist condition of peat soil and could reduce CO₂ emission by 47.6% (Zakiah et al. 2016). Another promising technology innovation for mitigating climate change is paludiculture. This technology could reduce CO₂ emission through creating a wet condition in peat soil; therefore peat oxidation could be reduced. Soil management for peatlands is also important because peat soils are acid and infertile. Fertilization and amelioration are needed to increase the pH and improve soil fertility. The household survey resulted that 53% of rice farmer applied ameliorant. Since ameliorant application will reduce CO₂ emission, therefore this action can be categorized as mitigation action for climate change.

Zero burning technology for land preparation is also important in mitigating GHG, since Varma (2003) claims that slash and burn for land clearing and preparation generated forest fires which is a source of CO₂ emission in peatlands. Fortunately, based on the household survey this action was done by most farmers in their farming. Ploughing soil using tools such as a plough or tractor engine is done by a farmer for soil preparation.

Revitalizing agricultural extension institution and establishing fire brigade

Although innovative technology for peatlands has been developed by research institutes and universities based on the in-depth interview with experts, adoption rates by farmers still need to be increased. It can be indicated from the survey result that only 40%, 47.25% and 33.33% of farmers in rice, oil palm and rubber farming system, respectively understood that peatlands is a major source of GHG. Thus more efforts on dissemination of innovative technology through agricultural extension agent are needed. Based on the expert judgment, agricultural extension institutions in the peatlands should be improved by emphasizing farmers’ need and strengthening farmers’ group. Revitalization of agricultural institution system should also be implemented in the context of climate change mitigation of the degraded peatlands. Furthermore, strengthening the extension institution through improvement field extension staff capacity in knowledge and skills of climate risk management, and dissemination of innovations technologies in climate risk management by technology demonstration, farmer field day, and CFS is needed to mitigate climate change.

In addition, based on FGD result, forest fire management is another mitigation action for reducing GHG emission in degraded peatlands management. An in-depth interview with the experts suggested that farmers and other community who live around peatlands forest should be involved in the forest fire management. The direct involvement of the communities in forest fire management can also encourage public awareness of forest fire. This can be realized through the establishment of Fire Brigade at the community level which is mandated to (1) support forest fire prevention through monitoring and surveillance in the village area; (2) perform operational actions of forest fire as quick as possible in its territory; (3) support land management activities (zero burning); and (4) coordinate with relevant agencies of forest fire control for the purposes of prevention and fire extinguishing (Adinugroho, et al., 2005).

Improving farmer experience and knowledge on climate change

Farmers’ understanding on GHG emission is an important factor in climate change mitigation of degraded peatlands because only 67%, 48.75%, 41.67% of farmers in rice, oil palm and rubber farming system, respectively were familiar with GHG emission. This is reinforced by only 40%, 47.25% and 33.33% of farmers in rice, oil palm and rubber farming system, respectively understood that peatlands is a major source of GHG. However, strategy for improving farmer knowledge in GHG emission should be aligned with the strategy for strengthening agricultural extension institution because field agriculture extensions play an important role for disseminating knowledge and information in dealing with climate change. Improving farmers’ knowledge, especially in sustainable peatlands agriculture, can be done through farmers’ capacity building by training and field school. It is an effective process for transferring climate knowledge to farmers; therefore, all farmers understand sustainable peatlands agriculture and fully adopt and apply it as suggested by expert judgment.

All those strategies should be implemented through effective coordination and synergy of all relevant stakeholders including Ministries, Government Institutions, Entrepreneurs, Academic Institutions, Non-Government Organizations and local community. Furthermore, it also requires commitment, role and contribution of these stakeholders to harmonize those strategies with the policies in relevant sectors. Similar recommendations were proposed by Regina et al., (2016) who recognized the importance of converging such strategies with policy, by stating that the climate change mitigation strategies can be meaningfully implemented if they are supported by relevant policies, especially national regulation and strategies.
Conclusion

Although farmers have adequate experience in peatlands farming system, not all farmers have knowledge and understanding of climate change and sources of climate change. Otherwise, there are farmer’s existing practices which have been done for mitigating climate change in their farming system such as:

- land preparation,
- water management, and
- soil management.

As peat soil has physical and chemical characteristic limiting the soil and water management, developing proper strategies for climate change mitigation is important to be done. Based on the analysis of key driving variables and scenario development, strategies for climate change mitigation through sustainable peatlands agriculture consist of:

- constructing canals blocking system,
- introducing innovation technology especially for soil and water management,
- revitalizing agriculture extension institution and establishing fire brigade, and
- improving farmer’s experience and knowledge in climate change through farmer training and climate field school.

Since CO$_2$ emission from degraded peatlands has become an international issue, the implementation of those strategies needs effective coordination and synergy among all relevant ministries, regional administrative units (from province to the lowest level), and other stakeholders both at the national and international levels, in line with the national development plan, applicable laws and UNFCCC agreements and related international conventions.

Competing Interests

The authors have no competing interests to declare.

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