Theme 2: Inclusive and sustainable SEAP

Discussion Paper No. 5

Potential Biochar Hotspots in the GMS and Recommended Actions*

The Discussion Paper Series of the Greater Mekong Subregion's (GMS) Core Agriculture Support Program Phase 2 (CASP2) is a platform for stakeholders of the GMS to examine the current and emerging development concerns affecting the subregion especially on but not limited to, food safety and quality assurance, environmental sustainability, and inclusive agro-based value chains. The papers are posted at the GMS Working Group of Agriculture's (GMS WGA) website (www.gms-wga.org).

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Abbreviations

AINS	-	Agriculture Information Network Services
CASP2	-	Core Agriculture Support Program, Phase 2
GMS	-	Greater Mekong Subregion
ha	-	Hectare
kg/ha	-	kilogram/hectare
Lao PDR	-	Lao People's Democratic Republic
NPK	-	nitrogen, phosphorus, and potassium

Executive Summary

This policy note summarizes the biochar study conducted under Asian Development Bank technical assistance (TA 8163). The study's objective was to develop the "biochar hotspots" in the Greater Mekong Subregion (GMS). This paper describes the preparation of maps to determine the areas best suitable for biochar production and use, and the results of pilot trials in the GMS.

Biochar is a carbon rich product created when biomass such as wood, manure, and leaves is heated with little or no available oxygen. Biochar production and application into soils offer multiple potential benefits, including

- storing organic carbon in the soil, thus providing climate change mitigation benefits;
- significantly improving soil quality;
- reducing farmers' input costs by 25%–50%, increasing crop yields, and increasing farmers' incomes;
- supplying efficient and renewable energy; and
- being appropriate for small-scale farmers.

Devising the biochar hotspots map entailed a four-staged process. First, a soil map was developed, using information on the characteristics of soil types. Second, data on topography were juxtaposed on the soil map to produce a soil suitability for biochar map of the GMS. Third, land-use features, focusing on the availability of agricultural and animal waste suitable for biochar production, were overlaid on the soil suitability for biochar map. And fourth, data on the GMS economic corridors were added to identify the biochar hotspots in the GMS. The hotspots are

- Svay Rieng and Kampong Chhnang provinces in Cambodia;
- Luliang County in Qujing District in Yunnan Province and Gangbei, Xingbin, and Yongning districts in Guangxi Province in the People's Republic of China;
- Nay Pyi Taw Council and Shwe Bo District in Myanmar;
- Savannakhet and Vientiane provinces in the Lao People's Democratic Republic;
- Kalasin, Nakhon Pathom, Nakhon Ratchaima, and Rayong provinces in Thailand; and
- Binh Thuan, Binh Dinh, Tay Ninh, and Vinh Phuc provinces in Viet Nam.

Through a letter of agreement arrangement between ADB and the concerned GMS agriculture ministries, on-farm research and demonstration of the multiple benefits of biochar application were carried out from early 2015 to the end of 2016. Two case studies were presented. The use of biochar in the production of baby corn in Thailand showed improved soil quality, reduced production costs, increased yield, and higher net incomes for the farmers. The case study in Cambodia used biochar in rice and vegetable production. As in the Thai case, soil quality improved; yields improved significantly, especially for the formula that used 50% biochar and 50% animal waste; and farmers' production costs were lowered and net incomes increased, and in fact doubled, in vegetable production. Women farmers were highly satisfied as they were the main producers of vegetables.

The empirical modeling applied by Viet Nam's Institute of Agriculture Environment showed that biochar application reduced greenhouse gas emissions and benefited farmers' incomes and health.

Biochar application is an option that can be presented to small-scale farmers in the GMS toward more inclusive and sustainable approaches for diversifying their products and expanding their revenue streams. There is merit in at least up-scaling the pilot experiences in the identified biochar hotspots to study more options for biochar use and development and more systematically and widely validate the benefits–costs of biochar development. The end-purpose of the exercises is to provide a menu of options from which farmers may choose in order to enable them to switch from excessive use of agrochemicals to approaches that are beneficial to their well-being, economy, and environment. Such a switch will result in more climate-resilient and gender-responsive methods of farm production. Biochar development should also be considered as an option for paving the GMS' pathway to becoming the ASEAN regional hub for safe and environment-friendly agriculture products and value chains.

Several actions are recommended to support the switch.

- In the immediate future (1) expand the farm areas using biochar; (2) update the soil map and share it in the Agriculture Information Network Services; (3) provide capacity building; and (4) improve market links.
- Investments in research and development are needed to (1) determine the appropriate ratio of biochar to animal wastes that will maximize farmers' returns; (2) in the medium term, investigate mangrove vegetation for sustainable biochar production; (3) investigate more sustainable approaches such as biochar development and support biochar innovation laboratories, possibly through public–private ventures; (4) enhance

research and analytical capabilities for biochar and soil analyses in the GMS, particularly in Cambodia, the Lao People's Democratic Republic, and Myanmar; and (5) conduct long-term field experiments comparing biochar with traditional fertilizer treatments for monitoring the agronomic and environmental benefits of biochar with the existing systems.

- Policy measures could include (1) incubator schemes, (2) smart subsidies, (3) inter-trade relations for development of biochar value chains, and (4) development of regulatory frameworks.
- Institutional measures could include (1) a biochar network and center, (2) clustered production and a logistics center, and (3) media links.

1. Introduction

In 2014, the Asian Development Bank funded technical assistance (TA 8163) for implementing the Core Agriculture Support Program, Phase 2 (CASP2). Under CASP2, the study on biochar hotspots in the Greater Mekong Subregion (GMS) was conducted.[1] The overriding purpose of the study was to evaluate the potential application of biochar technology in the GMS comprising Cambodia, Yunnan Province and Guangxi Zhuang Autonomous Region of the People's Republic of China (PRC), the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam. The specific objectives were to (1) locate "biochar hotspots" by developing a spatial map of the soil types in the GMS that are appropriate for biochar feedstock or biomass, and (2) suggest appropriate pilot sites in the GMS as priority areas for future investment to promote safe and environment-friendly agrobased value chains.

This paper summarizes the findings of the report (footnote 1) and updates the results with the actual experiences of the GMS pilot sites. The last section of the paper puts forward some immediate and medium-term actions for up-scaling the application of the biochar technology to promote the production of safe and environment-friendly agriculture products in the GMS.

2. Biochar and its Importance

Biochar is the carbon rich product that results when biomass such as wood, manure, and leaves, is heated with little or no available oxygen (Figure 1). The production and application of biochar can help store carbon and improve soils.

Figure 1: Biochar Production and Application

[1] The full report can be downloaded from http://icem.com.au/biochar/ **Soil Types and Biochar Land Application Suitability and Hotspots**

Note: Photos show how biochar is produced with kiln equipment (left) and how it is used in a field (right).
Source: ICEM, 2015

The production and application of biochar offer multiple potential benefits (Figure 2) as biochar provides a means to

- store organic carbon in the soil on a very long-term (millennial) scale, thus helping to mitigate climate change;
- significantly improve the soil by releasing nutrients, reducing nutrient leaching and gaseous losses, decreasing acidity, increasing water holding capacity, and regenerating the soil's microfauna and biological function;
- reduce input cost (especially the cost of using chemical fertilizer, by 25%-50%), improve nutrient use efficiency, increase crop yields, and consequently increase farmers' incomes;
- generate efficient and renewable energy;
- sustainably manage green wastes; and
- assist stallholder GMS farmers through a technology appropriate for them.

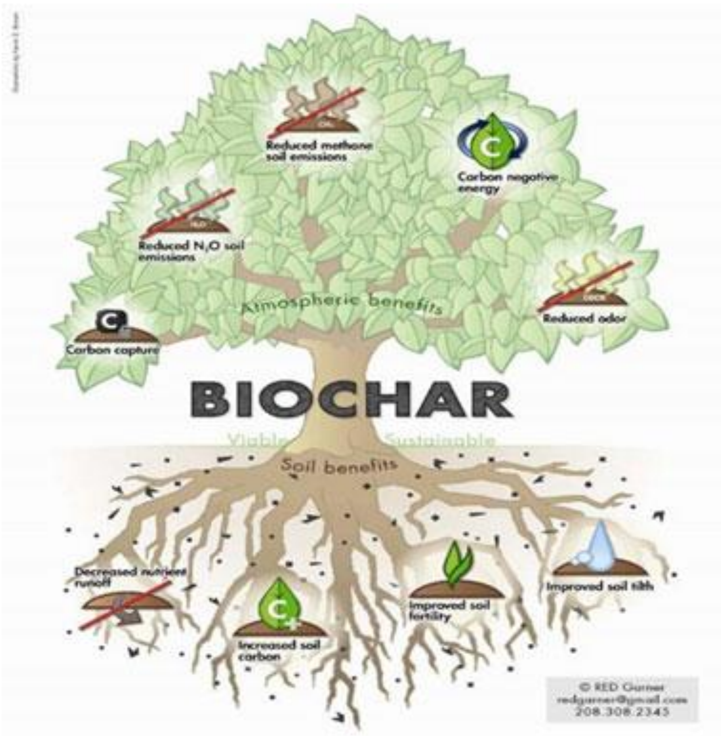

Figure 2 Biochar Benefits

Source: International Biochar Initiative. http://www.biochar-international.org/biochar

3. A Biochar Hotspots Map

In developing the biochar hotspots map, a four-stage process was followed. The stages are discussed below.

3.1. GMS soil map

To identify the biochar hotspots in the GMS, a soil map was first constructed using available data on soil properties (Figure 3). For the GMS region, the suitability of soils for biochar was determined based on soil properties, specifically pH, percent base saturation, texture, depth, and slope steepness.

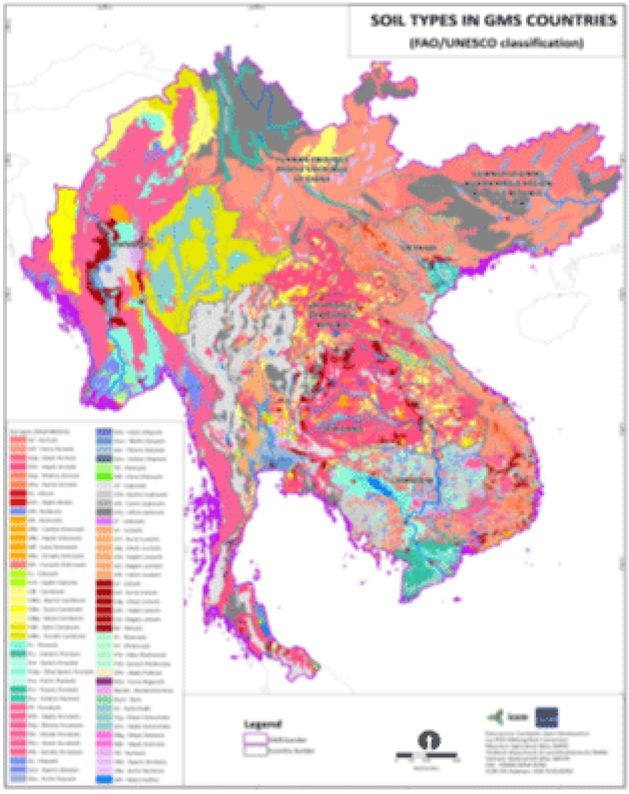

Figure 3 Soil Type Map for the Greater Mekong Subregion

As can be gleaned from Figure 3, the GMS has diverse soils, with four key features.

- Nearly 65% of GMS soils are acrisols, ferralsols, and leptosols. The majority of these soils have physical and/or chemical limitations on their use for crop production. The important soil constraints include shallowness, the presence of stones and rocks, low fertility, acidic pH, and insufficient phosphorus.

- About 25% of the remaining soils are mostly cambisols, fluvisols, gleysols, and luvisols. These are the GMS's key agricultural soils. The inherent fertility of these soils varies from low to moderate in most cases, although some of the fluvisols and gleysols may have moderate to high fertility qualities.
- Significant areas (over 3.34 million hectares [ha]) are acid sulfate soils (thionic fluvisols and thionic gleysols), which are extremely acidic and thus present severe limitations to cropping.
- The GMS has more than 2.84 million ha of sandy soils (arenosols), which hold little water and have very low inherent capacity to supply and retain essential plant nutrients.

3.2. Soil type and topography

The second step was to identify the land suitability for biochar application. The soil type map was refined by juxtaposing on it information on topography or land slope. A biochar index was developed, incorporating soil types and land slope characteristics (Figure 4). Through the application of a geographic information system, a biochar suitability map was produced with five categories: (1) highly suitable (blue in Figure 4), (2) suitable (dark green), (3) may be suitable (lime green), (4) may not be suitable (gold), and (5) unsuitable (red).

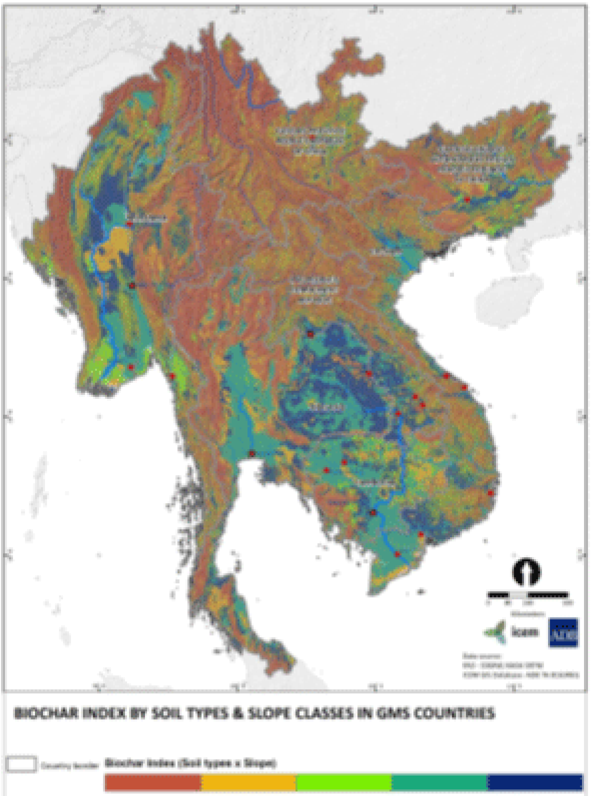

Figure 4 Suitability of Greater Mekong Subregion Soil for Biochar

3.3. Soil type, topography, and land use

The third step was to include land-use features (Figure 5), which focus on the availability of agricultural and animal waste suitable for biochar production. More than 104 million tons per annum of agricultural residues can be sustainably removed from GMS agricultural land and used for biochar production. The agricultural residues are predominantly based on rice production. Waste from rice cropping varies from a mid-range of 51% of crop residue as much as 84%, especially in the major rice belt areas of GMS countries.

Animal wastes, when enriched with essential plant nutrients, could serve as feedstock and can be added to crop residues and used for biochar production. Based on the total livestock and poultry population in the GMS, approximately 294 million tons of dry animal waste can be generated annually.

Due to the scattered presence of both agricultural residues and animal wastes, the major challenge for biochar production would be collecting the wastes. There is also significant competition from other uses of both waste materials in the GMS, such as for biogas and bioenergy production. Thus, a comprehensive economic and environmental analysis of potentially competing uses is needed.

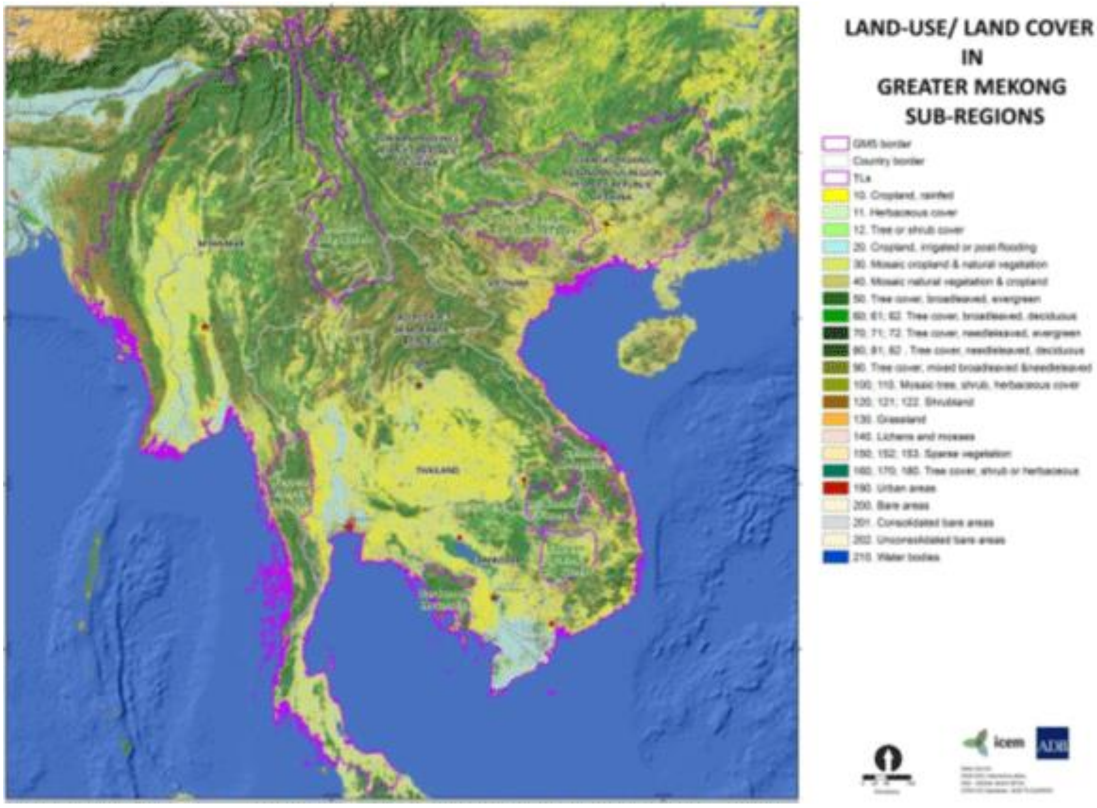

Figure 5 Greater Mekong Subregion Land Use Map

3.4. Biochar hotspots map

The last step involved overlaying the defined landscape traits of the GMS with the information on the GMS economic corridors. Biochar areas that are near economic corridors could serve as supply centers for the production of safe and environment friendly agrobased products using reduced agrochemicals and replacing them with biochar. Such areas are the GMS "biochar hotspots" (Figure 6), which would be the most suitable areas for biochar production. Based on suitability of the agricultural land to biochar production, potential biomass availability, and proximity to the economic corridors, about 2–4 biochar hotspots have been identified in each GMS country:

- Svay Rieng and Kampong Chhnang provinces in Cambodia;
- Luliang County in Qujing District in Yunnan Province and Gangbei, Xingbin, and Yongning districts in Guangxi Province in the People's Republic of China;
- Nay Pyi Taw Council and Shwe Bo District in Myanmar;
- Savannakhet and Vientiane provinces in the Lao People's Democratic Republic;
- Kalasin, Nakhon Pathom, Nakhon Ratchaima, and Rayong provinces in Thailand; and
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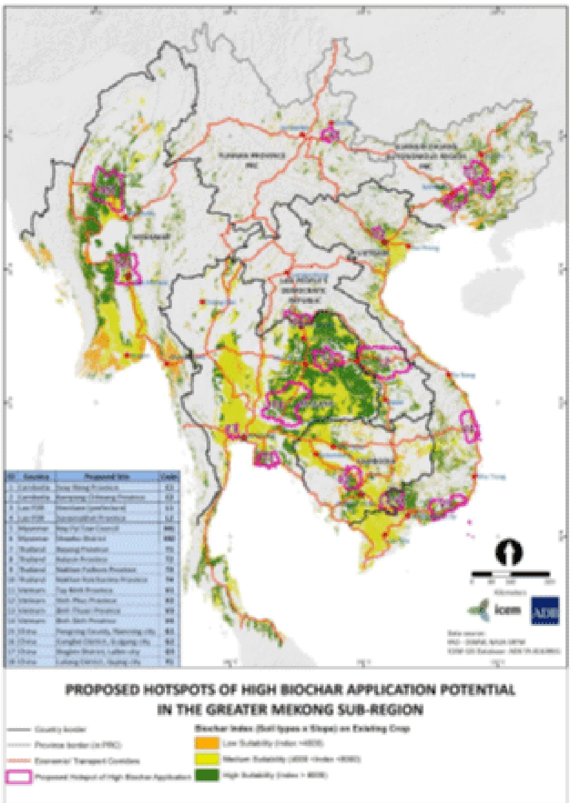

Figure 6 Proposed Hotspots Sites for Biochar Production in the Greater Mekong Subregion

3.5. Rice husk and straw for biochar production

Rice husk is perhaps the single most important agricultural waste that could be used as feedstock for biochar production. In addition, significant amounts of rice straw are burned in open fields, which has serious consequences for the local and regional air quality as high levels of particulate and toxic gaseous compounds are released into the atmosphere. Approximately 1.8 million tons of rice husk could be available annually for biochar production at the identified hotspots in the GMS. The conversion of rice husk into biochar could reduce the amount of carbon dioxide (CO_2) going into the atmosphere by over 1 million tons.

Additionally, rice husk biochar can reduce the consumption of potassium and phosphorus fertilizers by 20% and 100%, respectively. Rice husk biochar alone could reduce nitrogen fertilizers by only 4%, but this can be significantly increased if biochar is produced by mixing animal manure with rice husk.

Rice straw is being used for various purposes including animal feed, biofuel, organic fertilizer, and building material. Therefore, it is important to evaluate the economic and environmental viability of competing uses of rice straw (and other crop residues) in the GMS. This will provide the small-scale GMS farmers with information on what is the best use of their agriculture waste, other than the environmentally damaging option like open field burning.

3.6. The pilot tests

Through a letter of agreement between the Asian Development Bank and GMS ministries of agriculture, on-farm research and demonstration of the multiple benefits of biochar application were carried out from early 2015 to the end of 2016. In the field studies on baby corn in Thailand, 6 tons to 12 tons of biochar were applied per hectare. This helped to improve soil fertility as it reduced soil acidity, significantly increased the soil's organic matter content, and added important chemical elements such as phosphorus pentoxide (P_2O_5), potassium oxide (K_2O), calcium, and magnesium. The soil's physical properties were also improved, with an increase of moisture holding capacity, aeration, and aggregation. Biological functions were measured and an increased population of beneficial microorganisms that accelerate the decomposition of agriculture residues, such as *Actinomycetes*, other bacteria, and fungi, were also observed. With improved soil fertility, the average yield of baby corn increased by approximately 11%.

Extension of biochar application in 48 farmers' fields in four Cambodian provinces (Battambang, Kampong Chhang, Svay Rieng, and Takeo) also produced positive results. Trial and demonstration farms with rice and vegetables showed that the formula of applying 50% biochar and 50% slurry, compost, or cow manure at 2.5 tons/ha yielded the highest productivity vis-à-vis the conventional farmers' practice and the application solely of biochar. Tables 1 and 2 summarize these findings. With the same prices for rice and vegetables as those obtained from the conventional farmer's methods, the lower cost of production due to the use of biochar, and the higher yields, farmers' net incomes increased. Net revenues from the sale of vegetables that applied biochar were more than double those received by farmers who relied on synthetic agrochemicals. Women farmers were highly satisfied with the results, as majority of vegetable farmers were women. However, more research is needed to reduce the amount of labor needed to produce biochar.

Table 1: Average Rice Yield on the Demonstration Farms in Cambodia

Province	Average Rice Yield (tons/hectare)		
	T1 (biochar 100%)	**T2** (biochar 50%+ manure 50%)	**Control** (conventional practice)
Battambang	–	**4.95**	3.38
Kampong Chhang	3.50	**3.87**	2.83
Svay Rieng	–	**2.56**	2.37

Table 2: Average Vegetable Yield in the Demonstration Farms in Cambodia

Province	Average Vegetable Yield (tons/hectare)		
	T1 (biochar 100%)	**T2** (biochar 50%+ manure 50%)	**Control** (conventional practice)
Battambang	14.50	**21.75**	12.25
Kampong Chhang	29.25	**28.15**	20.90
Svay Rieng	48.00	**50.40**	47.00
Takeo	17.00	**23.50**	17.75

Biochar production yields byproducts that can be used as alternatives to synthetic agrochemicals. Vinegar collected during biochar production and fermented for 3–6 months can be sprayed on crops as a natural pesticide. It was also found that biochar mixed with slurry or compost can be used as basal fertilizer because biochar can kill most of the harmful soil-borne bacteria and fungi that cause plant disease. Biochar can likewise be added to animal feed to increase its nutritional value.

Figure 7 Biochar kiln demonstration (left) and vegetable farmer (right)

Application of biochar to soil in rice and vegetable growing areas also helped reduce greenhouse gas emissions, and thus contributes to mitigate the adverse effects of climate change. A study conducted by the Institute of Agricultural Environment in Viet Nam on rice grown in the summer and spring seasons of 2016 indicated that a 25% reduction of the use of NPK fertilizer and substituting biochar soil additions reduced the average methane from 496 kilograms per hectare (kg/ha) per season to 369 kg/ha/season, when compared with the normal (control) practice of nitrogen, phosphorus, and potassium (NPK) application. In addition, nitrous oxide emissions were reduced from 0.618 kg/ha/season to 0.482 kg/ha/season. This was equal to an average 26% reduction of carbon dioxide equivalent emissions from 12.584 kg/ha/season to 9.360 kg/ha/season. Rice yields also improved, by at least 2% when compared to the conventional practice of applying NPK. This study concluded that biochar application not only helps reduce the use of chemical fertilizer while increasing yields, but also mitigates greenhouse gas emissions from agriculture fields.

Because the study's sample size is small, the positive economic and environmental results and the other perceived societal benefits should be validated in wider trials. The societal benefits include that

(1) biochar technology is inclusive as it is tailored for easy and least-cost adoption by the small-scale farmers, the dominant actors in the agriculture sector;
(2) promotion of biochar application (versus use of synthetic agrochemicals) produced health benefits—households that switched to biochar application noted that since they applied biochar, they had not experienced dizziness and illnesses became less frequent;

(3) biochar use would reduce the import of synthetic agrochemicals, and thus contribute to foreign exchange earnings; and
(4) the increase in farmers' incomes hinges on their effective links to markets, consumer awareness of the benefits of lower exposure to agrochemicals, and consumers' willingness and ability to pay a price premium for such as health-related benefits.

More pilot trials are required to rigorously validate the medium- and long-term effects of biochar technology. This is especially important given the likely contribution to improved production of safe and environment- and gender-friendly agriculture products as well as enhancing the agro-based value chains for these products. On the basis of the study's results, there may be merit in scaling up the adoption of biochar at additional sites in the biochar hotspots, and conducting more research for maximizing the perceived benefits accruing from biochar application.

4. Recommendations

Given the economic, well-being, social, and environmental benefits observed in the trials using biochar, there may be merit in up-scaling the pilot experiences in the identified biochar hotspots to study more options for biochar use and development and to validate more systematically the benefits–costs of biochar development. The end purpose is to provide farmers with a menu of options that can enable them to switch from excessive use of agrochemicals to approaches that benefit their incomes, health, and environments, as well as resulting in more climate-resilient and gender-responsive methods of farm production. Biochar development should also be considered as an option for paving the way for the GMS to be the ASEAN hub for safe and environment-friendly agriculture products and value chains.

4.1. Immediate actions

Expand the farm fields using biochar. Set up more demonstration trials in farmer's fields in the identified GMS hotspot areas. Use the trials for demonstration and training, and for optimizing the biochar applications for rice and other crops. Biochar application could be encouraged in horticulture production for increased financial benefits and for developing sustainable production systems.

Update the soil map. The soil data will need to be updated and a revised soil map needs to be produced for the GMS. The revised map could benefit from the World Reference Base system, which is officially recommended as a sound source for soil type data by the

International Union of Soil Sciences and is thus being adopted worldwide (IUSS Working Group WRB, 2014). A unified and consistent GMS soil map will be an important resource for monitoring soil parameters, for future planning and for other environmental applications in the GMS. With the revised soil map and taking into account any emerging issues (such as policy or investment planning for promoting climate-friendly agriculture production), the biochar hotspots can be updated regularly and the information shared widely through the CASP2's Agriculture Information Network Services (AINS). AINS can also serve as basis for sharing knowledge and experiences on biochar application. Social media discussion forums will benefit both farmers and scientists like agronomists in the subregion.

Capacity building. In coordination with relevant national agencies, workshops and training programs should be organized to educate farmers and extension officials about biochar production and its potential economic and environmental benefits. Farmers who apply biochar technology to produce safe and environment-friendly products can be assisted to form groups that apply the participatory guarantee system to monitor the quality and safety features of farm production.

Market links. Farmers will need to be connected to markets, which is being tested in the CASP2 subprojects. Private sector collaboration will need to be strengthened to effectively link farmers to their consumer clients.

4.2. Investments in research and development

For wider scale use, biochar production will need to achieve scale economies that would keep pace with the growing population and increasing but changing agribased food preferences. To increase the nutrient supply capacity of biochar, animal wastes can be mixed with rice straw and other crop residues for producing biochar with better agronomic value. The appropriate mix for different soil types and farming conditions requires further research.

In the medium term, mangrove vegetation could be considered for sustainable biochar production.

More investments in sustainable approaches such as biochar development and biochar innovation laboratories will be needed. Investment funds can be joint ventures of the public and private sectors. Specific areas would be research and development for wider-scale biochar production and application that is less labor intensive as majority of the farmers who produce and apply biochar are women farmers.

Research and analytical capabilities for biochar and soil analyses in the GMS and particularly in Cambodia, the Lao PDR, and Myanmar are lacking and need to be addressed immediately.

Long-term field experiments (perhaps at experimental farms of national agencies and the private sector) comparing biochar with traditional fertilizer treatments should be established for monitoring agronomic and environmental benefits of biochar with the existing systems.

4.3. Policy measures

Incubator schemes. Adoption of biochar technology will require practical incentives from local and national governments in the initial stages to generate technologies that further improve yields from biochar, and technologies or equipment that lessen the labor used in the biochar production and application. This is especially relevant for women farmers. Incentives through start-up support or links with private sector in the form of incubator programs could be established for developing local technology for the collection of crop residues and animal wastes.

Smart subsidies. Smart subsidy schemes that encourage mechanization or mass production of biochar equipment and energy could be considered for biochar production in the hotspot areas identified in the study. The subsidies will need to be examined in terms of their implications on the fiscal situation of the country. The subsidy schemes will also have to be crafted in such a way that they are transparent, time-bound, and highly accountable to remove the potential for illicit rents.

In some cases, reduced tariffs may also be needed, especially for inputs that are required for biochar production but are not available in the country in large quantities. Many of the inputs are produced and supplied by the larger and better-off GMS economies. Bilateral trade initiatives can be forged to facilitate reduced or zero tariff schemes in line with the ASEAN[2] Economic Community principles. Trade facilitation measures will also have to be included in the initiatives to ensure smooth and least transactions costs at the borders.

[2] Association of Southeast Asian Nations.

Inter-trade relations for developing cross-border biochar value chains. Access to inputs for decomposing agriculture wastes, contractual labor arrangements for production and application of biochar, rental services for kiln equipment, exchange programs for scientists, development of research networks and centers of excellence on biochar, would benefit from easier cross-border movement.

Framework. A regulatory framework could be developed for permitting the use of waste materials as a biochar feedstock, biochar production methods, and classification of biochar in the GMS. Such measures would increase consumer confidence in the uptake of biochar technology. For this to happen, a biochar value chain analysis will need to be conducted.

4.4. Institutional innovations

Biochar network/center. Establish a GMS Biochar Center of Excellence and/or GMS Biochar Network to exchange and share knowledge and experience across the region. Countries such as Thailand are positioning themselves to serve as a knowledge hub for biochar. Public–private collaboration can participate in the promotion and development of biochar centers and networks.

Cluster approach. Institutional arrangements that enable cluster production would be needed. Concentration of biochar production in the identified biochar hotspots can be an option to serve the numerous but scattered GMS small-scale farmers more efficiently and effectively. The clustered biochar centers will also need novel contractual arrangements on the logistics, such as traders' delivery services. Additionally, invention of mobile kiln units that are practical and affordable for smallholder farmers needs research attention.

Media connection. Media need to be informed about the production and supply of safe and environment-friendly agriculture products, so they can disseminate it. A communications plan that provides periodic dialogues with the GMS Working Group of Agriculture and the domestic print and social media networks could raise awareness of climate smart agriculture methods such as biochar and agro-based value chains. This could serve as an impetus for developing the GMS as an internationally recognized hub of safe and environment-friendly agriculture products.

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About the Core Agriculture Support Program

The Core Agriculture Support Program (CASP) supports the GMS in attaining its goal of being a leading producer of safe food using climate-friendly agriculture practices. Now on its second phase, since 2012, CASP2 is committed to increasing the subregion's agricultural competitiveness through enhanced regional and global market integration and subregional connectivity.

The agriculture ministries of the six GMS countries supervise the implementation of CASP2 through the GMS Working Group on Agriculture (GMS WGA). A technical assistance (TA 8163) with financing from the Asian Development Bank, the Government of Sweden, the Nordic Development Fund, and the Water Financing Partnership Facility supports the CASP2 implementation. The GMS WGA oversaw the development of the discussion papers.

About the Asian Development Bank

ADB's vision is an Asian and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to a large share of the world's poor. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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