Biochar as a Solution for More Resilient Agriculture and Tackling Climate Change

Solution Overview and Initial Policy Recommendations

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WHITE PAPER

Biochar as a Solution for More Resilient Agriculture and Tackling Climate Change: Solution Overview and Initial Policy Recommendations

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Abbreviations

BAPPENAS	Badan Perencanaan dan Pembangunan Nasional (Indonesia's Ministry of National Development Planning)
BCR	Biochar Carbon Removal
CH4	Methana
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
GHG	Greenhouse gas
IDR	Indonesian Rupiah
N2O	Nitrous oxide
NGO	Non-Government Organization
NET	Negative Emission Technology
NPK	Nitrogen, Phosphorus, and Potassium fertilizers
P4G	Partnering for Green Growth and the Global Goals
RAN API	Rencana Aksi Nasional Adaptasi Perubahan Iklim (National Action Plan for Climate Change Adaptation)
USAID	United States Agency for International Development
USD	United States Dollar
WEF	World Economic Forum

Contents

Acknowledgement 7

Executive Summary 8

Section 1: Background 10

Section 2: What is Biochar 14

Section 3: Biochar as a Solution for More Resilient Agriculture 22

Section 4: Tackling Climate Change: The Potential of Biochar 35

Section 5: Biochar Policy Roadmap: Strategy, Governance and Market Access 45

Section 6: The Future of Biochar in Indonesia 51

Section 7: WasteX - Bina Tani and AdaKarbon Strategy and Action Plan 57

Conclusions 61

Contact 62

Appendix 63

List of Figures

Figure 1. Potential economic losses from climate change impact in priority sectors 10

Figure 2. Indonesia's rice harvest production (2018-2024) 11

Figure 3. Projected decline in rice production (2020-2045) by province 12

Figure 4. Indonesia total contribution of emissions in the agriculture sector 13

Figure 5. Benefits of biochar for agriculture and the environment 16

Figure 6. Effect of biochar on the productivity of different crops under various ecologies 17

Figure 7. Impact of various fertilizer-biochar combinations on corn yields 18

Figure 8 . Effect biochar application on the yield of Rice (WasteX Trial) 19

Figure 9. Biochar contributions to climate change mitigation 21

Figure 10. Biochar contributions to climate change adaptation 21

Figure 11. Good practices of biochar implementations in agriculture 22

Figure 12. Farmers participated in training and demonstration plots 25

Figure 13. Maize Yield, Cost, Revenue, Income Before and After Adopting Biochar 28

Figure 14 Paddy Yield, Cost, Revenue, Income Before and After Using Biochar 30

Figure 15. Correlation Cost Production to Yield, Revenue and Income (All Crops) 32

List of Figures

Figure 16. Production costs, revenue and income, comparing the costs from previous (before adopting biochar) and current seasons (after adopting biochar) 33

Figure 17. Crops Yield, Cost, Revenue, Income in Treatment Plots 34

Figure 18. Systemic mechanism of biochar in soil and plant system 39

Figure 19. The benefits of effective biochar policy governance for Indonesia 55

Figure 20. Strategic Steps for Biochar Policy Design in Indonesia 56

Figure 21. Framework for Biochar Adoption on the National Scale 63

List of Tables

Table 1. Estimated annual by product of agricultural biomass by product and their potential as raw materials for producing biochar	15
Table 2. Soil carbon analysis (before and after biochar application)	20
Table 3. Comparison table of biochar vs humic acid vs agricultural lime	23
Table 4. Demonstration Plots Establishment of Biochar Solution Implementations in Farmers Land (April - November 2024)	25
Table 5. Testimony by Farmers (May - September 2024)	35
Table 6. Potential biochar production and economic benefits of WasteX facility in Indonesia	40
Table 7. Potential benefits of biochar application for rice smallholders	40
Table 8. Potential benefits of biochar application for corn smallholders	42
Table 9. Economic and environmental impact calculations of national-scale biochar adoption in rice crop production	43
Table 10. Economic and environmental impact calculations of national-scale biochar adoption in corn crop production	45
Table 11. Policy recommendations for biochar governance in Indonesia	49
Table 12. Indonesia's biochar governance roadmap	56
Table 13. Action plan for advocacy on national biochar adoption	58

Acknowledgement

As climate change intensifies worldwide and threatens food security, it underscores the urgent need for agriculture that is both climate-resilient and carbon-negative. As part of the solution, WasteX - Bina Tani Sejahtera Foundation and AdaKarbon partnership offers a sustainable approach: biochar.

Biochar is derived from agricultural waste heated in high temperatures. As explained in-depth later, this material can become a key input for sustainable farming by enhancing soil health, improving crop yields, and reducing carbon emissions at the same time.

The collaboration leverages WasteX's biochar technology expertise, AdaKarbon and Bina Tani Sejahtera local outreach and training capabilities. Supported by P4G — an initiative focusing on climate action in food, water, and energy — it equips farms with onsite biochar production and training, with the goal of increasing yields and livelihoods of farmers across Indonesia as well as reducing 700 tons of carbon emissions annually.

As we embark on this initiative, we extend our appreciation to P4G Partnerships that enable us to realize this project. We also recognize the vital contributions of our biochar facility partners, local farmer groups, and all related stakeholders who share our commitments. Their collective efforts are essential to fostering sustainable, climate-resilient agriculture across Indonesia.

WasteX

BIOCHAR AS A SOLUTION FOR MORE RESILIENT AGRICULTURE AND TACKLING CLIMATE CHANGE: SOLUTION OVERVIEW AND INITIAL POLICY RECOMMENDATIONS

Executive Summary

Indonesia is one of the most vulnerable countries to climate change. Not only does climate change impact Indonesia's economic potential, but it is also causing extreme food crises, particularly in the agricultural sector. According to an economic assessment by USAID, by 2024, Indonesia could potentially lose IDR 78 trillion due to climate change impacts on agriculture. Future challenges for the agricultural sector are exacerbated by the conversion of agricultural lands into commercial and residential areas. Additionally, the lack of clarity in the agricultural roadmap and insufficient government support for farmers contribute to growing insecurity for Indonesian farmers. Furthermore, agricultural land degradation due to excessive use of chemical fertilizers poses another significant barrier to progress in Indonesia's agriculture.

Biochar is a carbon-rich solid material produced from organic waste (agricultural biomass) through incomplete combustion in limited oxygen supply (pyrolysis). The implementation of the biochar project in collaboration with P4G demonstrates that biochar can enhance agricultural productivity by increasing crop yields. It also contributes to climate mitigation by preventing the release of carbon into the atmosphere, thereby reducing greenhouse gas emissions. Additionally, biochar plays a critical role in soil health by restoring essential nutrients and improving water retention capacity. Furthermore, the adoption of biochar technology has the potential to support carbon sequestration in the agricultural sector, offering significant economic benefits through carbon capture and storage mechanisms.

As an integrated solution in the agricultural sector, it is supported by extensive research and practical implementations. Biochar not only enriches soil but also empowers farmers with higher crop yields. With its carbon-rich content, biochar enhances the soil's capacity to store water and nutrients. Environmentally, the production and application of biochar in agriculture also helps prevent greenhouse gas emissions from biomass burning and decomposition, as well as capturing carbon dioxide from the atmosphere.

In Indonesia, biochar has not been widely recognized by those directly involved in the agricultural sector. The national potential for agricultural biomass that can be converted into biochar is estimated at approximately 10.7 million tons, which could generate 3.1 million tons of biochar. The greatest potential is found in rice husks, which account for 6.8 million tons per year and would produce 1.77 million tons of biochar, representing about 56.48% of the total national biochar potential.

Meanwhile, Indonesia does not have accurate data on the level of biochar adoption. Limited support by the government to promote biochar applications, along with insufficient trials and restricted market access, has resulted in a low number of biochar adoption among farmers. Effective governance and applicability for biochar in Indonesia is crucial for addressing gaps in the agricultural sector, primarily to boost crop yields and contribute to food security, as well as to support carbon reduction efforts in agriculture.

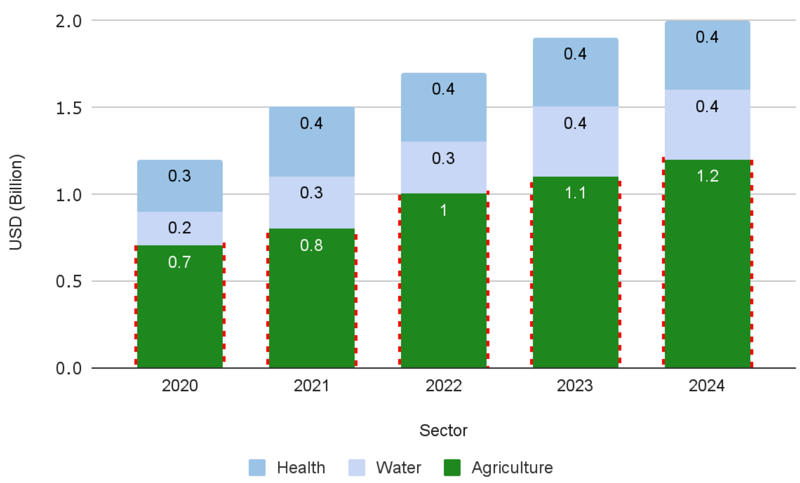
We recommend the implementation of a comprehensive and integrative policy for biochar governance in Indonesia. The potential of biochar to address agricultural and environmental challenges is closely aligned with Indonesia's goals of achieving food sovereignty and climate resilience in the future. Therefore, we believe it is essential for the Indonesian government to recognize and promote biochar as a valuable practice in the agricultural sector. Government recognition of biochar is crucial because it would facilitate large-scale adoption and utilization. Additionally, this recognition could open up the biochar market, fostering growth in the industry and benefiting small and medium-sized agricultural enterprises.

Section 1: Background

Climate change has become a global challenge. In Indonesia, it affects the rainfall cycle, increasing the incidence of prolonged droughts and extreme rainfall. According to the National Action Plan for Climate Change Adaptation (RAN API), climate change is projected to result in an economic loss of USD 28,12 billion between 2020 and 2024. In the agriculture sector, potential losses from climate-related crop failures may reach USD 5.2 billion (IDR 78 trillion) during this period if the government does not implement effective policies. The agriculture sector contributes 13% of Indonesia's total greenhouse gas emissions (GHG)[1]. in the RPJPN 2025-2045 document, the agricultural sector contributed a total of 98.7 Million tons of greenhouse gases in 2020[2].

Figure 1. Potential economic losses from climate change impact in priority sectors[3]

Source: Ministry of National Development Planning. National Action Plan for Climate Change Adaptation (RAN-API). 2019. Jakarta



Agriculture has always been one of the key factors in Indonesia's economy and people's livelihood. For instance, rice is a vital commodity in Indonesia, serving as a staple food for the majority of the population and playing a crucial role in ensuring

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[1] Low Carbon Development Indonesia. https://lcdi-indonesia.id/grk-pertanian/, accessed on 1/10/2024

[2] Ministry of National Development Planning. Rancangan Akhir Rencana Pembangunan Jangka Panjang Nasional. 2024. Page 52

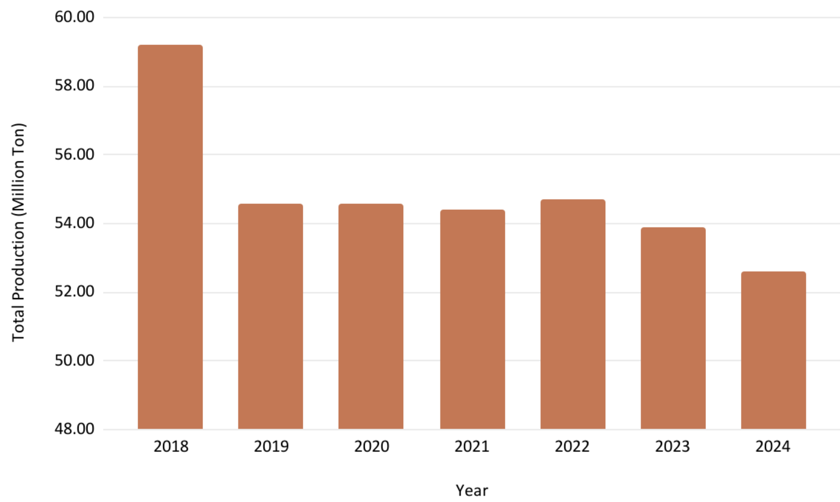
[3] Ministry of National Development Planning. *National Action Plan for Climate Change Adaptation (RAN-API)*. 2019. Page 4

the nation's food security. The rice sector continues to be a major source of employment in rural Indonesia, contributing 2.3% to the nation's GDP[4]. Amid increasing geopolitical tensions and global rice market instability, the government is actively working toward achieving rice self-sufficiency. Amongst the high demand on the commodity, however, there has been a reported decline in rice production in Indonesia.

Figure 2 shows how rice production in Indonesia has continued to decline from 2018 to 2024. According to data from BPS (Central Statistics Agency), this production decline is accompanied by a decrease in the harvested area each year, which is one of the contributing factors[5]. However, another significant factor is the impact of climate change, such as floods and droughts, which have affected Indonesia throughout the year. Climate data released by the Center for Agricultural Data and Information Systems shows that these climate-related events, especially droughts and floods, have had a major impact on the rice farming sector in Indonesia.

Figure 2. Indonesia's rice harvest production (2018-2024)

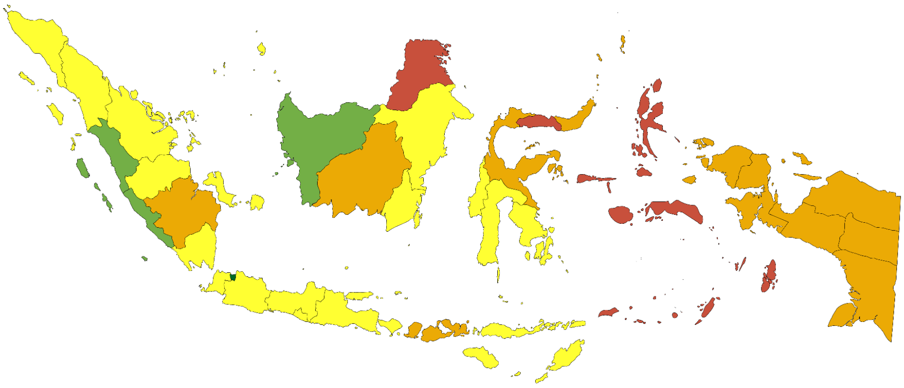
Source: BPS. Pertanian, Kehutanan dan Perikanan, 2024



[4] Katadata. https://databoks.katadata.co.id/agroindustri/statistik/56b59be1fc08d3d/sektor-pertanian-sumbang-124-pdb-2022-subsektor-apa-terbesar, accessed on 5 November 2024
[5] BPS. https://www.bps.go.id/id/statistics-table/2/MTQ5OCMy/luas-panen--produksi--dan-produktivitas-padi-menurut-provinsi.html, accessed on 5 November 2024

Meanwhile, based on a study by BAPPENAS, Figure 3 below shows the projected decline in rice production across all Indonesian provinces due to climate change, expected to occur by 2045.

Figure 3. **Projected decline in rice production (2020-2045) by province**



Source: Ministry of National Development Planning. Executive Summary: Climate Resilience Development Policy. 2021. Jakarta

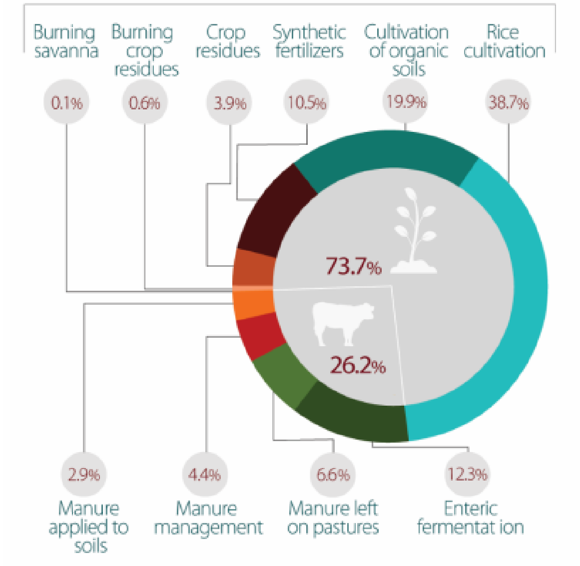
Rice Production Decline (2020-2045)		Province
(dark green)	(0%) – (-5%).	-
(green)	(-5.1%) – (-10.0%)	Sumatera Barat, Bengkulu, Kalimantan Barat
(yellow)	(-10.1%) – (-17.5%)	Nanggroe Aceh Darussalam, Sumatera Utara, Riau, Kep. Riau, Jambi, Kep. Bangka Belitung, Lampung, Banten, Jawa Barat, Jawa Tengah, Daerah Istimewa Yogyakarta, Jawa Timur, Kalimantan Timur, Kalimantan Selatan, Sulawesi Barat, Sulawesi Selatan, Sulawesi Tenggara, Bali, Nusa Tenggara Timur
(orange)	(-17.6%) – (-25.0%)	Sumatera Selatan, Kalimantan Tengah, Nusa Tenggara Barat, Sulawesi Utara, Sulawesi Tengah, Papua Barat, Papua.
(red)	< -25.1%	Kalimantan Utara, Gorontalo, Maluku Utara, Maluku

- Rice production in North Kalimantan, Gorontalo, Maluku, and North Maluku is projected to decrease by 25% from 2020 to 2045.
- The production in Java and Sumatra, known as the rice production centers, will also decrease by 10% to 17.5% or fall in the third moderate category.

To address climate change, the Indonesian government established the Nationally Determined Contribution (NDC) targets outlined in Presidential Regulation No. 98 of 2021. These targets include a GHG emission reduction goal of 29% by 2030 through domestic efforts alone, and up to 41% with sufficient international support.

Figure 4. Indonesia total contribution of emissions in the agriculture sector

Source: World Bank. Climate Smart Agriculture in Indonesia: Final Submission. 2021



In support of climate change mitigation in agriculture and to promote a climate-resilience industry, **We offer a comprehensive solution through biochar production and application for farmers and agri-producers.** This approach provides significant operational benefits, such as reducing the use of chemical fertilizers which contributes to 10.5% of emissions in the agriculture sector, increasing crop yields, and providing carbon credits payment. Additionally, it provides key environmental benefits, including improved soil health and reduced carbon emissions in agriculture.

Section 2: What is Biochar

Biochar is a carbon-rich material formed by heating organic materials (feedstock) at high temperatures in an oxygen-limited environment. This heating process, known as pyrolysis, stabilizes the carbon within the feedstock, transforming it into a stable form.

The incomplete combustion in a high temperature also results in a material that is highly porous with high surface area. This unique structure of biochar is the reason for its benefits in various sectors from agriculture, land remediation, to construction. Biochar's pores allow it to work like a sponge that retains water and nutrients, or absorbs toxic materials.

Biochar is mainly used in agriculture because of its capability to hold water and nutrients effectively, reducing nutrient leaching and improving fertilizers efficiency. Moreover, as a source of stable organic carbon, biochar can gradually improve soil organic carbon, encouraging microbial activity that sustains soil health over the long term.

By keeping these resources available longer in the soil, biochar promotes better crop health and increases yields. Numerous studies, as well as our own experience with biochar applications, have demonstrated its positive impact on plant growth and agricultural productivity.

From an environmental perspective, biochar mitigates climate change by removing carbon from the natural cycle of decay and atmospheric release, as it is trapped in a stable form. Furthermore, when produced adhering to certain standards, Biochar Carbon Removal has potential economic benefits from carbon credits, which will be explained in more detail in Section 4.

Indonesia has abundant raw materials to produce biochar. According to Sarwani et al. (2013) the national potential for agricultural biomass in Indonesia that can be converted into biochar is estimated at approximately 10.7 million tons. The biggest potential is found in rice husks, which account for 6.8 million tons per year, and it is representing about 56.48% of the total national biochar potential[6]. However currently there is no data available on how much biochar has been produced and distributed for adoption in Indonesia's agricultural sector.

Table 1. Estimated annual by product of agricultural biomass by product and their potential as raw materials for producing biochar

Agricultural Biomass	Amount (ton/year)	Assumption of convertible biomass (%)	Assumed amount of biomass convertible for biochar (t/year)	Biochar/ biomass ratio	Amount of potential biochar
Rice husk	13,612,343	50	6,806,172	0.26	1,769,605
Coconut shell	539,644	50	269,822	0.25	67,456
Palm kernel shell	6,400,000	30	1,920,000	0.50	960,000
Cocoa fruit shell	1,208,553	50	604,277	0.33	199,411
Corn stalk	3,652,372	30	1,095,712	0.13	142,443
Total	25,412,912		10,695,983		3,138,915

Source: Sarwani et al. (2013)

[6] Muhrizal Sarwani, Neneng Laela Nurida, and Fahmuddin Agus. *Greenhouse Gas Emissions and Land Use Issues Related to The Use of Bioenergy in Indonesia*. Jurnal Penelitian dan Pengembangan Pertanian 32(2). 2013. Page 63.

Figure 5. Benefits of biochar for agriculture and the environment[7]

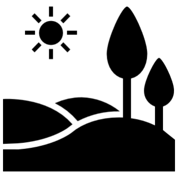
Agriculture

Biochar improves the water retention capacity of soils and, when combined with fertilizers, leads to yield increase and stability

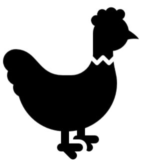
Biochar helps to build up soil carbon

Biochar reduces GHG emissions from agriculture

Biochar can be used as an additive in composting to improve compost quality and reduce nitrogen losses

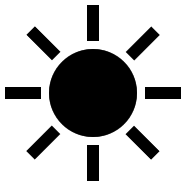


Biochar enables the rehabilitation of contaminated soils

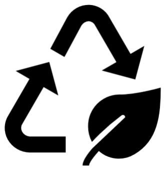


Biochar shows multiple benefits in animal husbandry and improves animal health

Environment

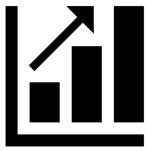


Biomass pyrolysis converts non-stable carbon in the biomass into a stable form, which can last in the soil for over 1,000 years

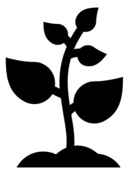


Pyrolysis can be used to close organic material cycles. This is a prerequisite for the principle of recycling in the bioeconomy

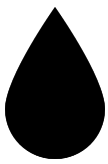
The use of certified biochar has been proven to meet the highest environmental standards and, when used properly, is safe for soils, ecosystems, and users



Biochar can improve the properties of concrete and asphalt



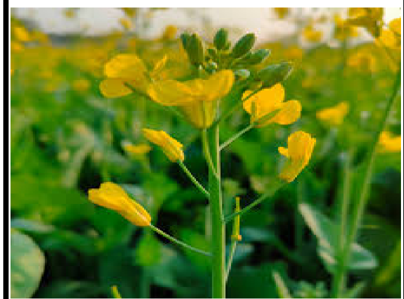
Biochar promotes tree growth and increases the stress resistance of urban trees



Biochar reduces nitrate pollution of ground and surface water

[7] EBI Whitepaper: “Biochar-based carbon sinks to mitigate climate change”. 2022. Freiburg. Page 28

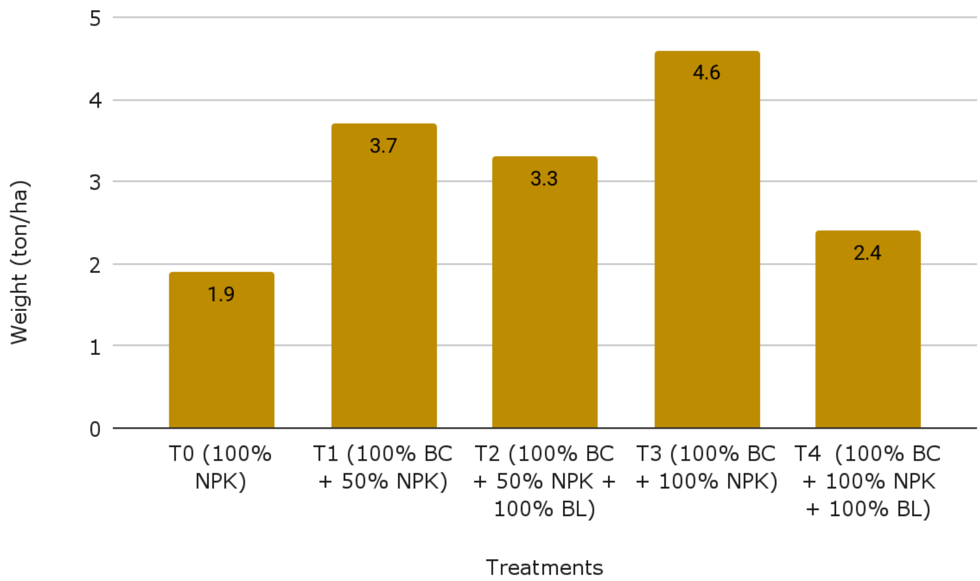
Figure 6. Effects of biochar on the productivity of different crops under various ecologies[8]

		
Wheat	**Rice**	**Cowpea**
São Paulo, Brazil	**Hunan, China**	**Kumasi, Ghana**
Straw biochar (20 ton ha−1)	**Rice husk biochar (20 ton ha−1)**	**Corn cob feedstock (5 ton ha−1)**
The grain yield was 2.91–19.4% higher over urea application at 200 kg ha−1	6% economic yield enhancement over control	Increased seed yield by 36% over control
		
Sesamum	**Garden Pea**	**Mustard**
Dhaka, Bangladesh	**Bule Woreda, South Ethiopia**	**Rasuwa, Nepal**
Biochar (6 ton ha−1)	**Lantana camara biochar (12 ton ha−1)**	**Eupatorium adenophorum shrub biochar (40 ton ha−1)**
18.8% higher yield over control	54% higher yield compared to corn cob biochar of the same application rate*	Increased grain yield by 134% compared to control

Source: Subash Babu. Biochar implications in cleaner agricultural production and environmental sustainability. 2023

[8] Subash Babu. Biochar implications in cleaner agricultural production and environmental sustainability. 2023

Figure 7. **Impact of various fertilizer-biochar combinations on corn yields (WasteX Trial** [9]



* 100% BC (Biochar) = 2.5 tons/ha
* 100% NPK = 250 kg/ha
* 100% BL (Biofertilizer) = 3 litres/ha
* Planted during dry season

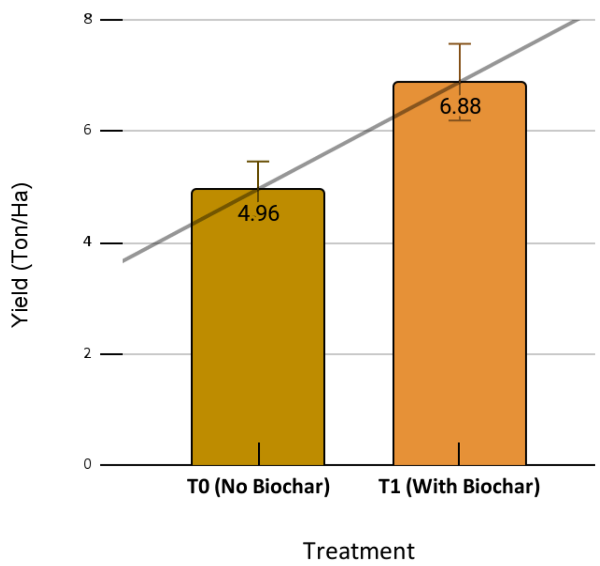
Source: WasteX, Biochar Trial on Corn Project Documentation, 2024

[9] WasteX. Project documentation on biochar trial on corn. 2024

Key Results

- Biochar addition can improve corn yield (dry grain weight) by up to 147% compared to control (no biochar).
- A combination of biochar and biofertilizer can reduce the need of chemical fertilizers (NPK) by up to 50% while also improving corn yield to 73%.

Figure 8 . Effect biochar application on the yield of Rice (WasteX's Trial)



T0 : Biochar 0 kg as control

T1 : Biochar 10 kg / plot (2 ton/ha)

Key Results

- Rice plots (T0) that use waste bedding biochar charged with urea yield are 38% higher than plots without addition of biochar.
- Biochar is also better able to retain water in rice fields so that the plants can absorb nutrients better.

Table 2. Soil carbon analysis (before and after biochar application)

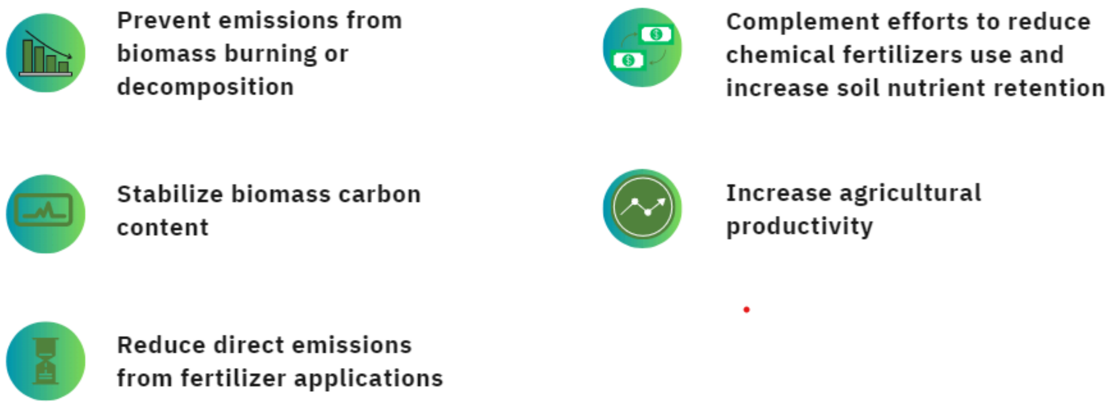
Parameters	Initial soil	After Biochar Application	After Harvest
C-organic (%wt)	1.52	1.48	5
C-inorganic (%wt)	0.35	0.41	0.37
Total C (%wt)	1.87	1.89	5.37

Source: WasteX, Biochar Trial on Corn Project Documentation, 2024

Key Results

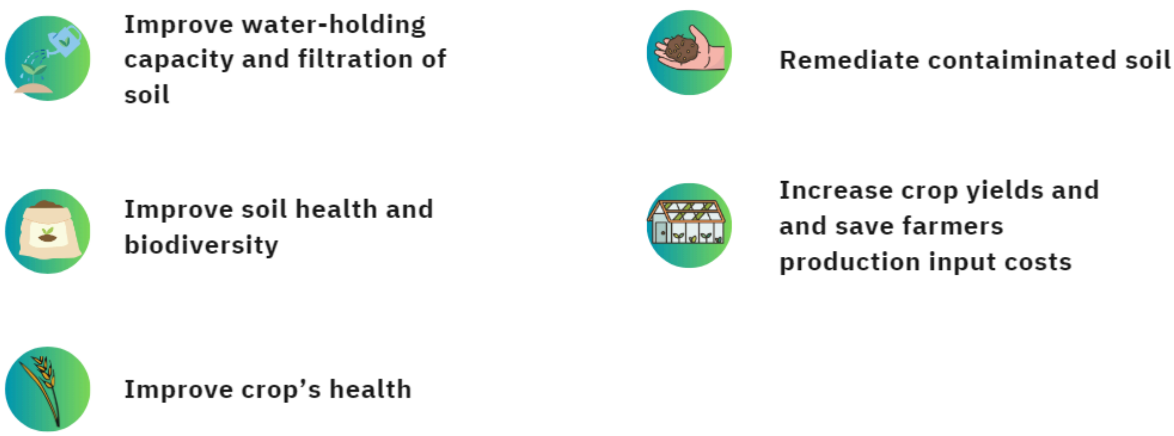
Adding 2.5 tons of biochar per hectare increases total soil carbon, especially soil organic carbon (SOC), by ~237% within 3 months. SOC improves soil aeration, water retention capacity, drainage, and enhances microbial growth. Furthermore, soil carbon provides a source of nutrients through mineralization, helps aggregate soil particles (structure) to provide resilience from physical degradation, increases microbial activity, increases water storage and availability to plants, and protects soil from erosion.

Figure 9. Biochar contributions to climate change mitigation[10]



Source: Gaunt, J., & Cowie, A. Biochar, Greenhouse Gas Accounting, and Emissions Trading. Earthcon, 2009.

Figure 10. Biochar contributions to climate change adaptation



Source: Environmental and Energy Study Institute. Biochar and compost for climate change adaptation. 2022.

[10] Gaunt, J., & Cowie, A. *Biochar, Greenhouse Gas Accounting, and Emissions Trading*. Earthcon, 2009.

Section 3: Biochar as a Solution for More Resilient Agriculture

Good practices of biochar implementation in crops have been widely practiced, especially to promote sustainable agriculture and climate-resilient crops.

Figure 11. **Good practices of biochar implementations in agriculture**

Biochar implementation on Coffee in San Ramon, Peru, and Tanzania[11]	Biochar Implementation in Cotton Farming in Zambia[12]
	
Biochar application promotes healthier coffee plants, improves soil health, and up to 35% increases in yield.	The use of biochar in cotton farming in Zambia has increased yields by up to 250% and reduced dependence on chemical fertilizers.

[11] Kathleen Draper, *The Potential for Biochar to Improve Sustainability in Coffee Cultivation and Processing: A White Paper*
[12] Solidaridad, https://www.solidaridadnetwork.org/news/biochar-revitalizes-cotton-farming-in-zambia/, accessed on 08/01/2024

Biochar stands out among soil amendments like humic acid and agricultural lime due to its unique ability to address multiple agricultural and environmental challenges simultaneously. As described in the detailed comparison table below (Table 3), biochar must be considered amongst other soil amendments as a sustainable and eco-friendly solution to boosting agricultural productivity while supporting environmental conservation by its ability to sequester carbon and how it's mostly produced from agricultural wastes.

Table 3. Comparison table of biochar to the other popular soil amendments, i.e. humic acid and agricultural lime

Feature	Biochar[13]	Humic Acid (*Asam Humate*)[14]	Agricultural Lime (*Kapur Pertanian*)[15]
Type	Organic soil amendment	Organic soil conditioner	Soil pH adjuster
Source	Pyrolysis of organic materials (wood, agricultural waste, etc.)	Humified organic matter from plants or compost, mining of leonardite/lignite (soft brown coal)	Calcium carbonate (limestone) from mineral mining/tailings
Main function	Soil improvement, carbon sequestration	Soil conditioning, nutrient retention	Raises soil pH (reduces acidity)
Physical form	Solid, charcoal-like particles	Powder or liquid	Powder, granular
Application	Mixed into soil, used for carbon storage or soil enhancement	Applied to soil or plants for nutrient uptake and soil health	Applied to soil to correct acidity (lower pH)
Effect on soil	Increases soil porosity, water retention, and microbial activity	Enhances nutrient absorption, soil aeration, and moisture retention	Increases soil pH, reduces acidity, improves nutrient availability
Effect on plant	Improves root growth, enhances plant health indirectly	Improves plant growth, root development, and overall vitality	Supports healthy plant growth in acidic soils

[13] J. Lehmann & S. Joseph. *Biochar for Environmental Management: Science and Technology*. 2015
[14] E. A. Ghabbour & G. Davies. *Humic Substances in Soil and Crop Sciences: Selected Readings.* 2001
[15] University of Minnesota. *Agricultural Lime: Benefits and Uses.* https://extension.umn.edu/planting-and-growing-guides/soil-acidification. Accessed on 03/12/2024

Nutrient Content	Low nutrient value; mainly improves soil structure	Rich in humic and fulvic acids, beneficial for nutrient uptake	Primarily calcium (Ca) and magnesium (Mg); no significant nutrients for plants
Environmental impact	Environmentally friendly; helps in carbon sequestration	Natural, eco-friendly soil amendment	Environmentally safe but should be used according to soil pH needs
Duration of effect	Long-lasting, improves soil for years because its stable carbon	Can be long-lasting but may need periodic reapplication Short to medium time because it's more chemically complex and biologically active	Long-lasting; depends on soil's initial pH
Effect on Soil pH	Can raise pH (alkaline), depending on the feedstock	Slightly acidic to neutral; buffers pH fluctuations	Raises pH, neutralizes acidic soils

Source: Processed by WasteX. 2024

Figure 12. Farmers participated in training and demonstration plots

Table 4. Demonstration Plots Establishment of Biochar Solution Implementations in Farmers Land (April - November 2024)

Location	Type of Crops	On-going	Completed harvest	Total
Batang	Chilli	4		4
(Central Java)	Cucumber	4		4
	Maize	3		3
	Paddy	16	3	19
Grobogan	Bittermelon	1		1
(Central Java)	Chili	1		1
	Maize	1		1
	Shallot	1		1
Pasuruan	Chilli	1		1
(East Java)	Maize	5	10	15
	Paddy	18	15	33
	Tomato	1	1	2
Malang	Maize		1	1
(East Java)		**56**	**30**	**82**

Source: P4G Project Documentation

During April - November 2024, we trained a total 223 smallholder farmers in the 10 Training of Farmer Event series held in the East Java and Central Java area. Amongst them, we identified 82 smallholder farmers as the biochar beneficiaries that already applied biochar in their demo plot farm as well as the key farmers that influence others to adopt biochar technology (Figure 12) by their testimonials (Table 5). The number of the waiting list of smallholder farmers that have willingness to adopt biochar keeps increasing. It represents that all these interactions with the farmers encourage them to use biochar as soil amendment, yield improvement, and resulting income increment.

As shown in Table 4, we have 56 demo plots still ongoing and 30 demo plots completed (harvested) in these 82 farmers' lands (Figure 12). This broad scope highlights biochar's versatility and its applicability across different crop types. Our primary goal is to facilitate farmer-driven biochar adoption by demonstrating its benefits on crop productivity and soil health.

Key components of the implementation process include:

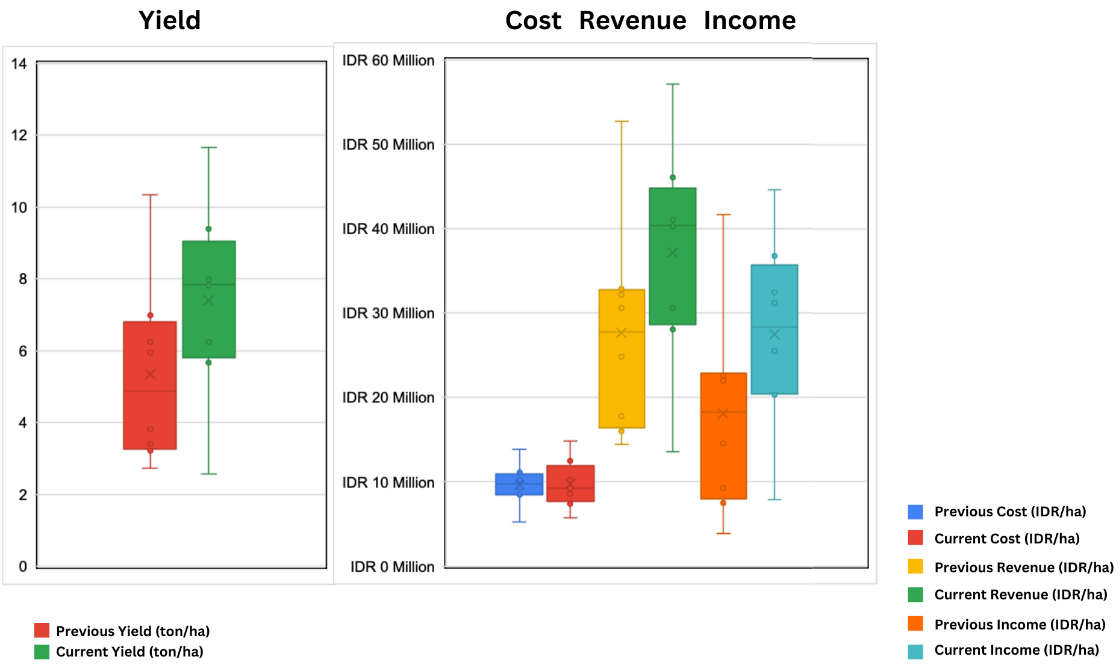
- Introduction and Training: Farmers receive comprehensive training sessions on biochar production, application techniques, and its potential benefits.
- Mentoring and Consultations: Continuous support is provided, focusing on Good Agricultural Practices (GAP) to ensure effective and sustainable integration of biochar into farming routines.
- Demonstration Plots: Farmers are encouraged to establish comparison plots. They apply biochar with reduced fertilizer doses in one section while maintaining traditional practices in another. For those hesitant to reduce fertilizers, the project suggests incorporating biochar alongside current practices and comparing the resulting yields with previous seasons.

Several challenges have emerged during implementation:

- Farmer Skepticism: Some farmers remain uncertain about biochar's efficacy, necessitating continuous education and field demonstrations.
- Coordination Difficulties: The predominance of older farmers presents challenges in supervision and adopting new technologies.
- Institutional Support: Limited backing from regional agricultural departments has necessitated increased efforts in community outreach and engagement.

The project's progress underscores biochar's potential to revolutionize modern agriculture by improving yields and promoting sustainable practices. Continued support, adaptive strategies, and demonstrative success stories will be essential to overcoming existing challenges and fostering broader adoption. Through collaborative efforts, we aim to transform these initial strides into long-term, impactful agricultural advancements.

Figure 13. **Maize Yield, Cost, Revenue, Income Before and After Adopting Biochar in Pasuruan**



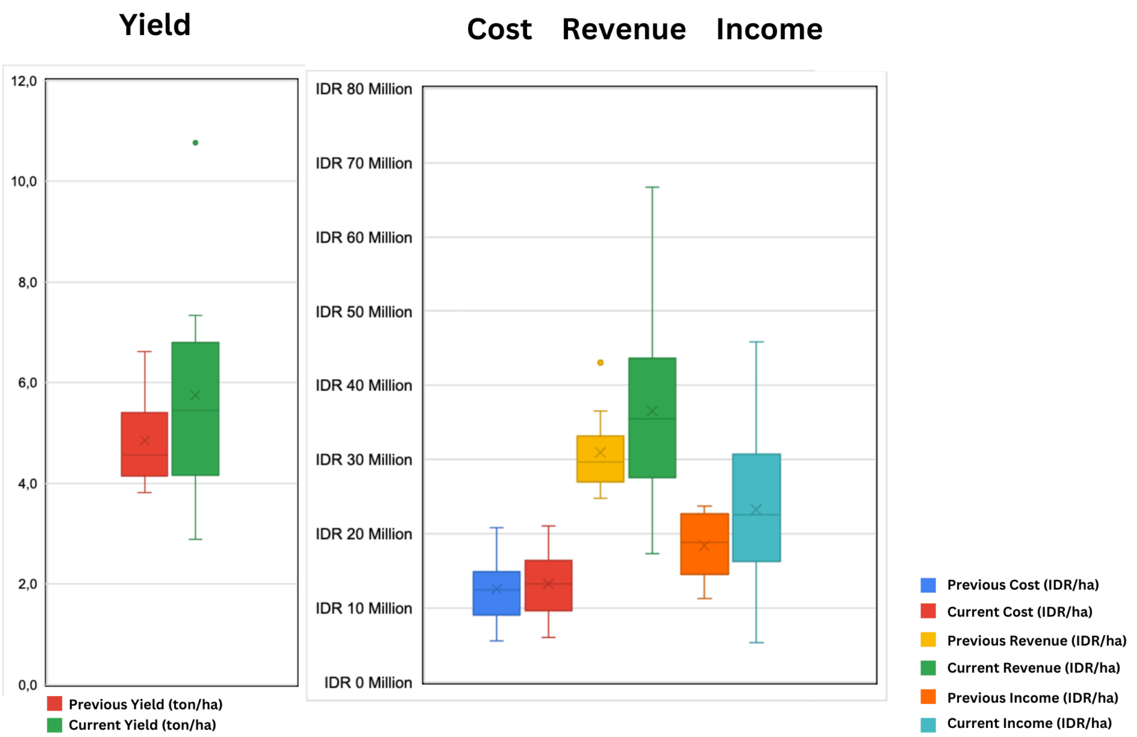
Source: P4G Project Documentation

During May to September 2024, we distributed biochar to corn/maize farmers in Pasuruan. We collected parameters on the yield results, cost, revenue, and income from the harvest of the current planting season (with addition of biochar 2~2.5 ton/ha) and the previous planting season (that did not use biochar, same land, same crops). We tested the normality of the yield, cost, revenue, and the income using The Kurtosis-Skewness test. The results of skewness and kurtosis of all parameters value at range $-2 < x < 2$, indicating the normality of data ($p = 0.05$). Therefore, the data meets the assumptions for parametric testing.

The figure 13 shows clear improvements in several key metrics with the use of biochar. In terms of yield, we recorded a remarkable yield increase from approximately 5 tons/ha in the previous season to around 7.5 tons/ha with biochar. Cost data, however, remained relatively stable, with the median cost hovering around IDR 8-12 million/ha in both scenarios, showing that biochar application did not significantly increase or reduce production costs. Compared to other places in Indonesia, corn farmers in various provinces spend around IDR 6-15 million/ha as the planting budget and based on the Indonesian Statistical Bureau, while Indonesian corn productivity in 2024 was 5.8 ton/ha. This result shows that applying biochar in the field has increased the productivity range where previously our farmers stood below the Indonesian mean, now they're 20% above the national average.

Revenue, on the other hand, experienced a notable rise. The median revenue tends to increase from about IDR 28 million/ha in the previous season to approximately IDR 38 million/ha with biochar, showing trend points to economic benefits. This increase in revenue translated into higher income, with median income rising from around IDR 10-12 million/ha to approximately IDR 24-25 million/ha. The income data also shows greater variability but demonstrates a clear upward trend. In summary, the application of biochar led to substantial improvements in yield, revenue, and income without increasing costs, highlighting its effectiveness and economic viability for enhancing agricultural productivity.

Figure 14. **Paddy Yield, Cost, Revenue, Income Before and After Using Biochar (in Pasuruan)**



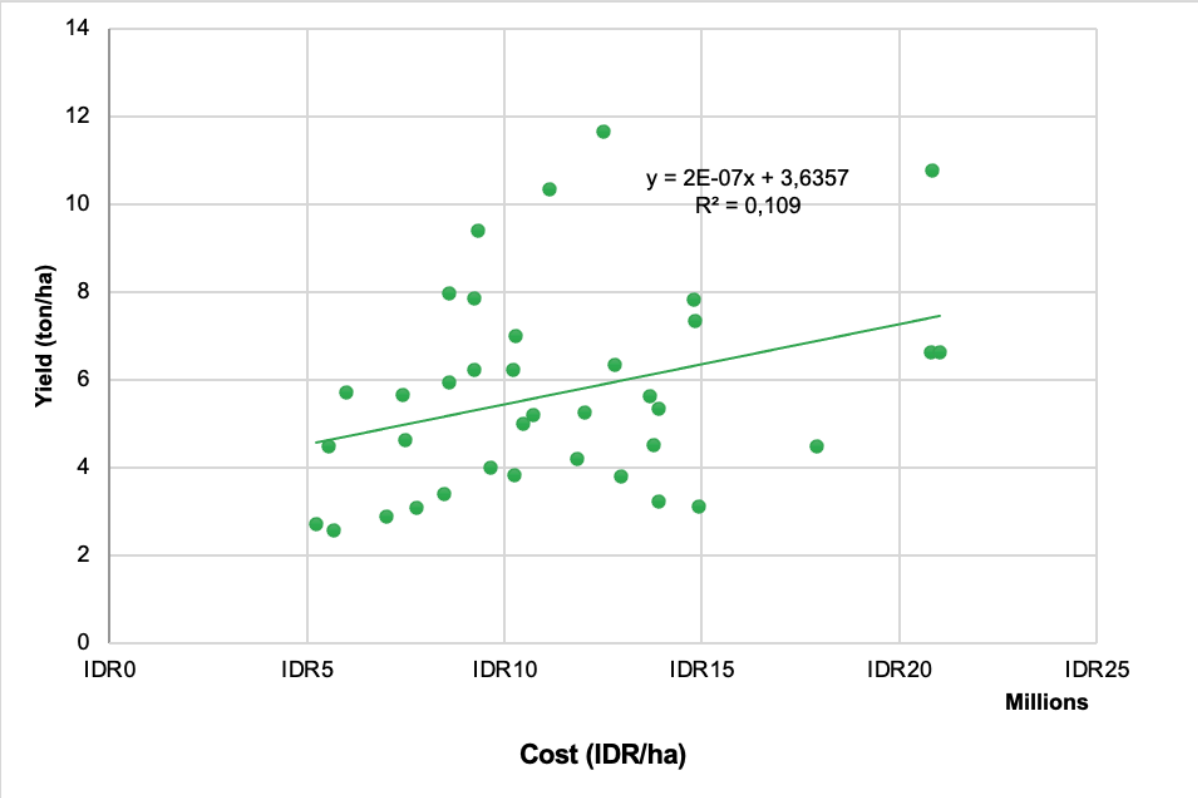
Source: P4G Project Documentation

During May to September 2024, we distributed biochar to rice/paddy farmers in Pasuruan. We collected parameters on the yield results, cost, revenue, and income from the harvest of the current planting season (with addition of biochar 2 ton/ha) and the previous planting season (that did not use biochar, same land, same crops). We tested the normality of the yield, cost, revenue, and the income using The Kurtosis-Skewness test. The results of skewness and kurtosis of all parameters value at range $-2 < x < 2$, indicating the normality of data ($p = 0.05$). Therefore, the data meets the assumptions for parametric testing.

The figure 14 shows clear improvements in several key metrics with the use of biochar. In terms of yield, we captured there is improvement in productivity because the median value rose from approximately 5 tons/ha in the previous season to around 6.5 tons/ha with biochar. Cost data, however, remained relatively stable, with the median cost hovering around IDR 12-14 million/ha in both scenarios, we assumed that biochar application did not significantly increase production costs. Instead, by adopting biochar into their practice, there is potential of productivity improvement (yield).

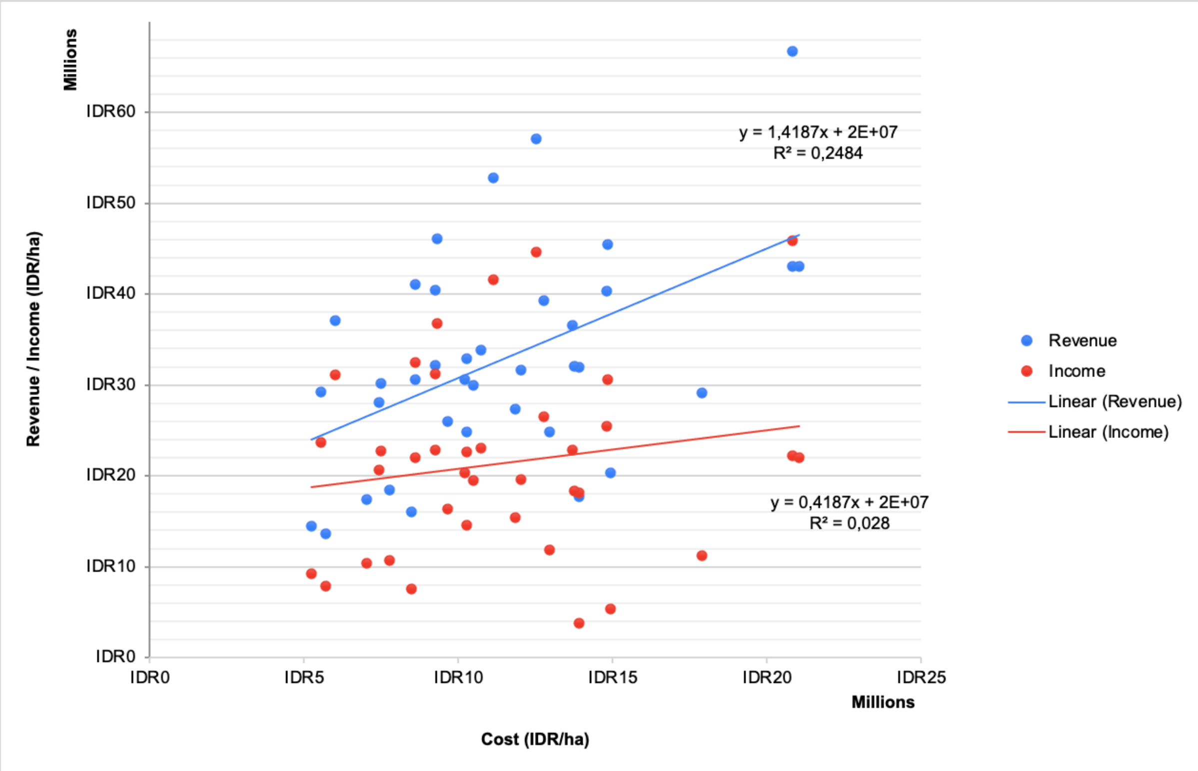
Revenue, on the other hand, experienced a notable rise. The median revenue tends to increase from about IDR 24 million/ha in the previous season to approximately IDR 40 million/ha with biochar, so that indicating trend points to significant economic benefits. This increase in revenue translated into higher income, with median income rising from around IDR 10-12 million/ha to approximately IDR 24-25 million/ha. The income data also shows greater variability but demonstrates a clear upward trend. In summary, the application of biochar could lead to substantial improvements in yield, revenue, and income without increasing costs, highlighting its effectiveness and economic viability for enhancing agricultural productivity.

Figure 15. **Correlation Cost Production to Yield, Revenue and Income (All Crops)**



The data shows a positive relationship between production costs (X) and crop yield (Y), as indicated by the trendline. This suggests that adoption of new technology such as biochar into farmer's cost correlated with higher yields. However, while higher production costs are generally associated with higher yields, costs alone do not explain the variation in yields. Factors such as crop management practices, soil quality, weather conditions, or biochar application methods likely also play a substantial role. The wide dispersion of data points around the trendline further highlights the variability in yield outcomes, even at similar cost levels.

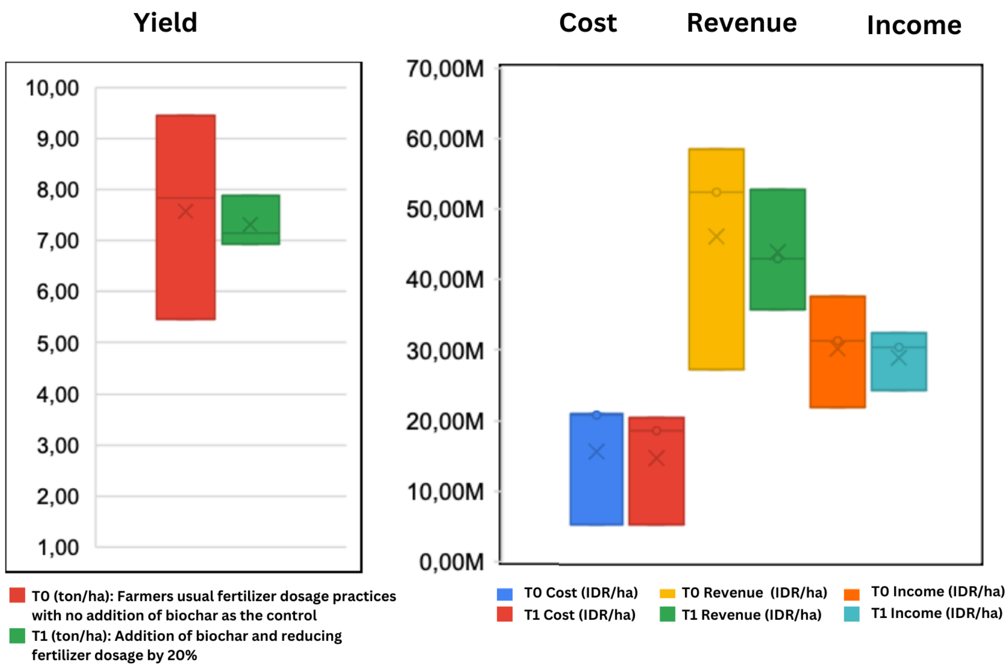
Figure 16. Production costs, revenue and income, comparing the costs from previous (before adopting biochar) and current seasons (after adopting biochar)



The figure 16 shows the relationship between production costs and both revenue and income, comparing the costs from previous (before adopting biochar) and current seasons (after adopting biochar). In the previous planting season, costs included land preparation, seeds, labor, fertilizers, pest and disease management, and harvesting. For the current season, biochar costs were added to these various existing expenses. The positive trend lines indicate that higher production costs are generally associated with higher revenue and income. Therefore, the addition of biochar appears to influence revenue and income.

The wide dispersion of data points around the trendlines implies that other factors—such as biochar application efficiency, soil quality, market conditions, or crop management practices—may have a more significant effect. While biochar might contribute to improving yields and profitability, assessing its cost-effectiveness in combination with these factors is essential for optimizing overall production outcomes.

Figure 17. Crops Yield, Cost, Revenue, Income in Treatment Plots in East Java and Central Java



Source: P4G Project Documentation

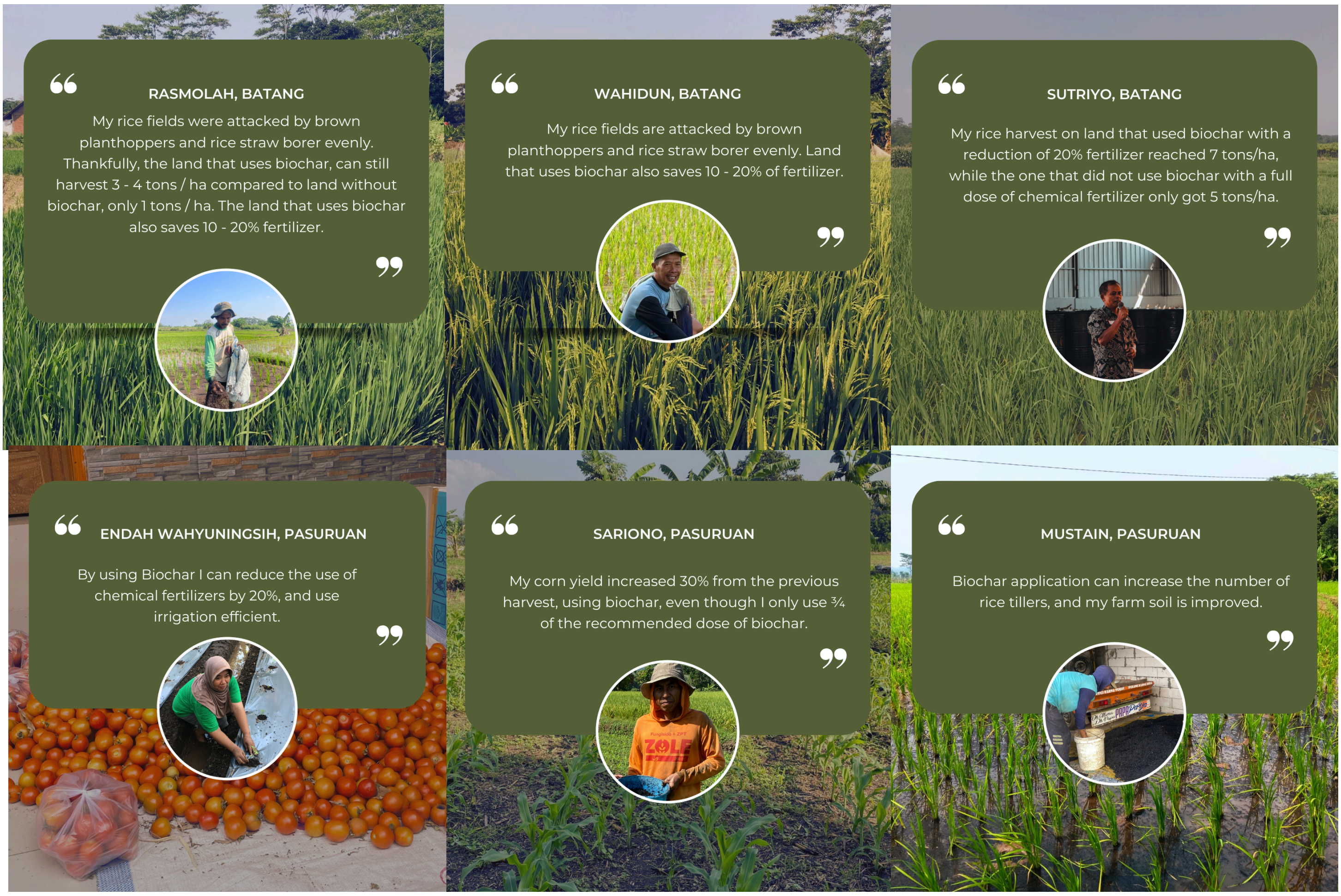
During our implementations with farmers in East Java and Central Java, we also recommend the committed farmers to do demonstration plots to explore the benefit of biochar in reducing chemical fertilizer dosage. We divide the farmers field into T0 and T1 in the same planting season, in T0 plot farmers uses their usual fertilizer dosage practices with no addition of biochar as the control, while in T1 we add biochar with recommended dosage per respective crops and reduce the chemical fertilizer dosage by 20%.

Figure 17 showed the range of yield, cost, revenue, and income in T0 and T1. For yield, T0 outperforms T1, producing around 9 tons/ha compared to T1's 7 tons/ha. This trend yield in T1 might be attributed to transitional challenges or environmental factors during the implementation of biochar. Statistically, costs reflect no significant investment required for this new practice. Consequently, the revenue in T0 is also higher, correlating with its higher yield, while T1 shows reduced revenue. This difference impacts income significantly, with T0 achieving better profitability, as it benefits from higher yields and lower costs.

Overall, the results suggest that the initial use of biochar might not yield immediate financial benefits, as reflected in T1's lower income. However, biochar's long-term advantages, such as improved soil fertility, may not yet be fully realized in the first season. These findings underline the importance of demonstrating biochar's potential over multiple cycles to address farmer skepticism and validate its effectiveness.

Revenue, on the other hand, experienced a notable rise. The median revenue tends to increase from about IDR 24 million/ha in the previous season to approximately IDR 40 million/ha with biochar. So the trend points to significant economic benefits. This increase in revenue translated into higher income, with median income rising from around IDR 10-12 million/ha to approximately IDR 24-25 million/ha. The income data also shows greater variability but demonstrates a clear upward trend. In summary, the application of biochar led to substantial improvements in yield, revenue, and income without increasing costs, highlighting its effectiveness and economic viability for enhancing agricultural productivity.

Table 5. Testimony by Farmers (May - September 2024)



Source: P4G Project Documentation

Key Results

- All the parameters (yield, cost, revenue, and income) were normally distributed using The Kurtosis-Skewness test. Therefore, the data meets the assumptions for parametric testing.
- Between April and November 2024, we conducted 10 Training of Farmers events across East Java and Central Java, reaching a total of 223 smallholder farmers. Among these participants, 82 farmers were identified as biochar beneficiaries, having already applied biochar on their demo plots. These farmers also act as key influencers, encouraging others to adopt biochar technology which are shown from their positive testimonials in adopting biochar technology. The growing waiting list of farmers eager to adopt biochar highlights the positive impact of these training sessions. These training interactions have successfully promoted biochar as a valuable soil amendment, improving yields and increasing farmers' incomes.
- The initiative involves the adoption of biochar by 82 farmers, in various crop types of staple and vegetable, with 56 demonstration plots currently in progress and 30 already completed (harvested) on the lands of these dedicated farmers
- The adoption of biochar is not significant in cost or investment. Further analysis shows a positive relationship between production costs (as X) and crop yield (as Y). This suggests that adoption of new technology such as biochar into farmer's cost correlated with higher yields.
- Further trial comparison of biochar with other soil amendments (humic acid, agricultural lime) shall be held to provide the best choice proof of biochar soil amendments amongst others.

Section 4: Tackling Climate Change: The Potential of Biochar

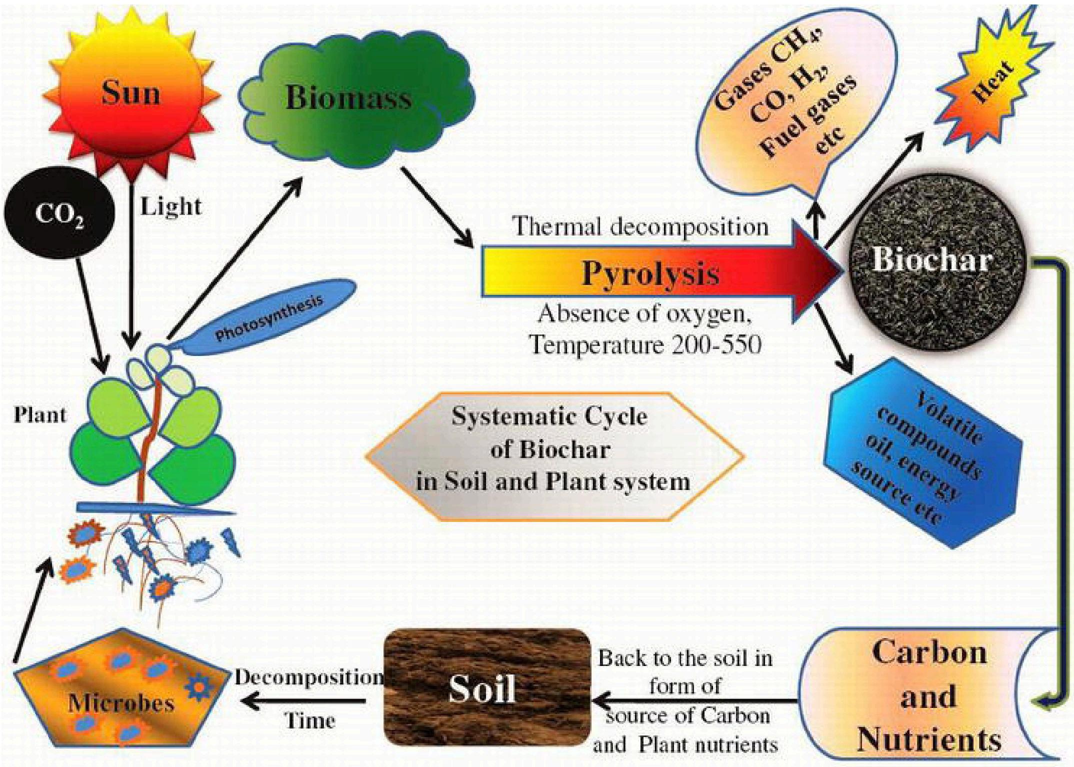
Biochar Carbon Removal (BCR) is a negative emission technology (NET) that actively removes carbon dioxide (CO_2) from the atmosphere and stores it in a way that prevents its release back into the environment. Biochar, as a form of NET, refers to a carbon-rich material produced by pyrolyzing organic biomass (such as wood, agricultural residues, or waste) in the absence of oxygen.

WasteX's Partner Facility in Batang, Central Java

Biochar Carbon Removal

As a carbon-rich material, biochar is produced by pyrolysis of organic biomass, such as agricultural residues, wood, and other plant matter, in an oxygen-limited environment. This process converts carbon in the feedstock into a stable solid form, allowing it to be stored for long periods and potentially mitigating climate change.

Figure 18. Systemic mechanism of biochar in soil and plant system



Source: Hanuman Singh Jatav. 2019. Importance of Biochar in Agriculture and Its Consequence

Biochar is made through the thermal decomposition of biomass in the absence of oxygen, usually at temperatures between 300-700°C. The carbon in biomass is retained in the biochar, which is chemically stable and resistant to microbial decomposition[16]

Biochar is highly stable and rich in carbon. This carbon is in a form that resists degradation for centuries or even millennia, making it an effective long-term carbon sink. When organic material is converted into biochar, a significant portion of the carbon in the biomass is retained in the solid biochar. By burying or applying biochar to soil, this carbon can be stored indefinitely, preventing it from re-entering the atmosphere as CO2, which would otherwise occur if the biomass decomposed naturally or was burned.

[16] Lehmann, J., Rondon, M., & Wirick, M. (2006). Biochar and the global carbon cycle. Biochar for Environmental Management: Science and Technology, 22-37.

Biochar Facilities in Indonesia

WasteX currently owns 3 biochar facilities in Indonesia, first is the joint project with a cornmill in Pasuruan, a cornmill where we are using corn cobs as the feedstock to produce biochar. Our second facility is our project with Berkah Puja Gathi in Batang where we use sawdust / wood chips as the feedstock. Previously, the biomass from our partner was typically burnt or left to decompose or sold for cooking fuel, animal feed and some other agricultural needs which emit greenhouse gases. After the deployment of the project, biomass from mills are utilized and turned into biochar, utilizing up to 31 tons of biomass per month, and producing up to 12,5 tons of biochar per month.

Per November 2024, we have distributed 27.4 tons of Biochar to 63 Farmers across Java. The peak occurs in November where we distributed 11.2 tons of biochar in a month. Our biochar distribution can be seen in the map below where red indicates higher amount of biochar than green area

Table 6. Potential biochar production and economic benefits of WasteX facility in Indonesia

Facility	Feedstock amount (ton/year)	Biochar production (ton/year)	CO2e impact (ton CO2e/year)	Potential Carbon credits (USD/year)	Potential biochar revenue (USD/year)
Corn mill	250-375	100-150	165-247	15000-22500	20000-30000
Sawmill	250-375	100-150	165-247	15000-22500	20000-30000

Assumptions:
Carbon credits price : 150 USD/ton
Biochar price : 200 USD/ton
Feedstock-biochar conversion : 40%

Economic Benefits of National-Scale Biochar Adoption in Indonesia

We have created scenarios for biochar adoption in terms of economic calculations in the agricultural and environmental sectors. The scenarios in the table below show how the potential economic and ecological benefits accrue in an Indonesia-scale adoption of biochar.

Table 7. **Potential benefits of biochar application for rice smallholders**

The table below shows the estimated economic and environmental benefits for rice smallholders using biochar on a land area of 0.5 ha.

Scenario	Yield (ton/year) *	Income (USD/year)	Emissions (ton CO2e/year) **	Carbon Capture (ton/year) ***	Potential Revenue (USD/year)* ***	Potential Net Profit (USD/year)
Baseline without Biochar	5.4	1,439.1	5.5	0.0	1,439.1	690.9
With Biochar	6.5	1,726.9	2.4	1.6	1,808.7	948.2
Difference	1.1	287.8	-3.1	1.6	369.6	257,4

* Twice a year harvest

** Emissions from fertilizers and decomposition of biomass

*** Carbon capture from biochar produced

**** Potential Revenue from yield improvement and carbon selling to biochar producer

Key Results

Per 0.5 ha of rice farming:

- Assumptions:
  - 25% reduction in chemical fertilizers
  - 20% increase in crop yields
  - 100% biomass converted into biochar
- Biochar application will increase rice production by 1.1 tons per year
- It will also decrease the use of urea and NPK fertilizers by 99.57 kg per year
- Impact on the CO_2e emissions from biochar activities:
  - Reduction of 3.1 tons CO_2e per year from avoiding biomass burning and/or decomposition, and fertilizer use reduction
  - Capture and storage of 1.6 tons of CO_2e per year from biomass conversion to biochar
- Potential revenue increase for farmers of USD 369.6 (IDR 5.9 million) per year:
  - Additional income from rice harvest: USD 287.8 (IDR 4.6 million) per year
  - Carbon credits income: USD 81.8 (IDR 1.3 million, assuming carbon credits payment of USD 50/ton of biochar)

Table 8. **Potential benefits of biochar application for corn smallholders**

The table below shows the estimated economic and environmental benefits for corn smallholders using biochar on a land area of 0.5 ha.

Scenario	Yield (ton/year) *	Income (USD/year)	Emissions (ton CO2e/year) **	Carbon Capture (ton/year) ***	Potential Revenue (USD/year) ****	Potential Net Profit (USD/year)
Baseline without Biochar	5.8	2,180.3	3.8	0.0	2,180.3	1319.0
With Biochar	7.0	2,616.3	1.3	2.4	2,734.1	1876.2
Difference	1.2	436.1	-2.4	2.4	553.9	557.2

* Twice a year harvest

**Emissions from decomposition of biomass and fertilizer

*** Carbon capture from biochar produced

**** Potential Revenue from yield improvement and carbon selling to biochar producer

Key Results

Per 0.5 ha of corn farming:

- Assumptions:
  - 25% reduction in chemical fertilizers
  - 20% increase in crop yields
  - 100% biomass converted into biochar
- Biochar application will increase corn production by 1.2 tons per year
- It will also decrease the use of urea and NPK fertilizers by 200.3 kg per year
- Impact on the climate from biochar activities:
  - Reduction of 2.4 tons CO2e per year from avoiding biomass burning and/or decomposition, and fertilizer use reduction
  - Capture and storage of 2.4 tons of CO2e per year from biomass conversion to biochar
- Potential revenue increase for farmers of USD 553.9 (IDR 8.8 million) per year:
  - Additional income from corn harvest: USD 436.1 (IDR 6.7 million) per year
  - Carbon credits: USD 117.8 (IDR 1.8 million, assuming carbon credits payment of USD 50/ton of biochar) per year

National Economic Benefits of Biochar Adoption in Rice and Corn Crop Production (0 - 100% rate adoption)

The table below shows the economic and environmental calculations in the biochar adoption for rice crops on a national scale.

Table 9. **Economic and environmental impact calculations of national-scale biochar adoption in rice crop production**

Scenario	National Yield (million ton/year) *	National Yield Income (USD/year)	Emissions (million ton CO2e/year)**	Carbon Capture (million ton/year)***	Potential Revenue (billion USD/year)****
Baseline, 0% adoption rate	109.8	29,388	111.6	0.0	29.38
10% adoption rate	112.0	29,976	105.3	3.3	30.14
100% adoption rate	131.8	35,266	48.3	33.4	36.93
Difference 0-10%	2.2	587,8	-6.3	3.3	0.76

* Twice a year harvest

** Emissions from decomposition of biomass and fertilizers

*** Carbon capture from biochar produced

**** Potential Revenue from yield improvement and carbon selling to biochar producer

Key Results for 10% Biochar Adoption in Rice Crop Production

Per 10% national area of rice farming:

- Assumptions:
  - 25% reduction in chemical fertilizers
  - 20% increase in crop yields
- Potential increase of rice production by 2.2 million tons per year
- Potential decrease in the use of urea and NPK fertilizers by 200 thousand tons per year
- Impact on the climate from biochar activities:
  - Reduce 6.3 million tons of CO2e per year from avoiding biomass burning and/or decomposition, and fertilizer use reduction
  - Capture and store 3.3 million tons of CO2e per year from biomass conversion into biochar
- Potential revenue increase for farmers of USD 760 million (IDR 12 trillion) per year:
  - Additional income from rice harvest: USD 587.8 million (IDR 9.3 trillion) per year
  - Carbon credits income: USD 172.2 million (IDR 2.7 trillion, assuming carbon credits payment of USD 50/ton of biochar)

Meanwhile, the table below shows the economic and environmental calculations in the biochar adoption for corn crops on a national scale.

Table 10. **Economic and environmental impact calculations of national-scale biochar adoption in corn crop production**

Scenario	National Yield (million ton/year)	National Yield Income (USD/year)	Emissions (million ton CO2e/year)*	Carbon Capture (million ton/year)**	Potential Revenue (billion USD/year)***
Baseline, 0% adoption rate	28.9	10,845	18.7	0.0	10.84
10% adoption rate	29.5	11,062	17.45	1.17	11.12
100% adoption rate	34.7	13,014	6.6	11.7	13.60
Difference 0-10%	0.6	216,9	-1.2	1.2	0.28

* Twice a year harvest
** Emissions from decomposition of biomass and fertilizer
*** Carbon capture from biochar produced
**** Potential Revenue from yield improvement and carbon selling to biochar producer

Key Results for 10% Biochar Adoption in Corn Crop Production

Per 10% national area of corn farming:

- Assumptions:
  - 25% reduction in chemical fertilizers
  - 20% increase in crop yields
- Potential increase in the amount of corn production by 0.6 million tons per year
- Potential decrease in the use of urea and NPK fertilizers by 0.1 million tons per year
- Impact on the CO2e emissions from biochar activities:
  - Reduce 1.2 million tons of CO2e per year from avoiding biomass burning and/or decomposition, and fertilizer use reduction
  - Capture and store 1.12 million tons of CO2e per year from biomass conversion into biochar
- Potential revenue increase for farmers of USD 280 million (IDR 4.3 trillion) per year:
  - Additional income from corn harvest: USD 216.9 million (IDR 3 trillion)
  - Carbon credits: USD 63.1 million (IDR 99.4 billion, assuming carbon credits payment of USD 50/ton of biochar)

Section 5: Biochar Policy Roadmap: Strategy, Governance and Market Access

Indonesia is lagging in terms of biochar utilization. With the limited support from government and the policies, the use and utilization of biochar in the agricultural and environmental sectors is low.

Following the example of the United States (USA), they show real support in accelerating the use of biochar in several sectors with programs such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP). Results show that financial support for farmers, government assistance, and wide-scale biochar use can fertilize crops and reduce dependence on organic fertilizers; shows improvement in soil health and contributes to carbon capture in the agricultural sector. In the environmental sector, the practice of using biochar as a soil amendment has been practiced in millions of hectares of conservation areas in the United States.

The Urgency of Biochar Policy in Indonesia

- In Indonesia, no regulation recognizes biochar in the agricultural or environmental sectors beside as a soil amendments;
- There is an urgency to include biochar as an integrated solution for agriculture and the environment in Indonesia. As part to support the RPJMN 2025-2029 target to increase agricultural productivity and create national food security[17]. Biochar should be considered to be included as one of the good practices in the agricultural sector. Ministry of Agriculture should immediately include biochar in the 2025-2029 strategic plan as one of their strategies in increasing productivity and ensuring environmental sustainability;
- The urgency to include carbon trading mechanism for biochar in Indonesia carbon market;.
- We strongly recommend to have specific endorsement for biochar product release, and with incentive for local entrepreneurs, start-ups etc to be engaged in the production-distribution-adoption continuum of biochar as key input for sustainable farming.

[17] Ministry of National Development Planning. *Ringkasan Rancangan Awal RPJMN 2025-2029*. 2024. Page 3-6

Integrated the target of RPJMN 2025-2029 with Biochar to achieve food security and environmental sustainability goals

The Ministry of National Development Planning has published an initial summary of the RPJMN 2025-2029. The vision carried in the RPJMN is aligned with the vision of Indonesia's elected president and vice president 2024-2029: Bersama Indonesia Maju Menuju Indonesia emas 2045. The Asta Cita mission in RPJMN there are at least two missions that are closely related with agriculture and environmental:

- Encouraging the nation's independence through self-sufficiency in food, energy, water and the Green economy (the second Asta Cita)
- Strengthening the harmonious harmonization of life with the environment and nature (Eighth Asta Cita)

The vision and mission are then elaborated in 17 presidential priority programs, some of which are relevant to the agricultural and environmental sectors:

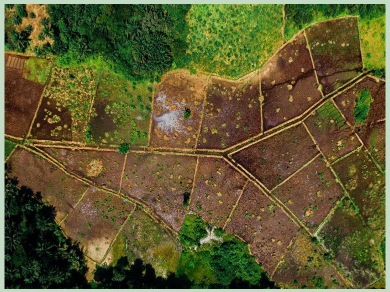
1. Food self-sufficiency
2. Ensuring the preservation of the environment
3. Ensure the availability of fertilizers, seeds, and pesticides directly to farmers

To pursue food self-sufficiency and environmental sustainability, the main focus of the work program is on creating new agricultural lands in Papua and Kalimantan, as well as increasing agricultural productivity by providing fertilizers, seeds, and other supporting infrastructure. Biochar, although not explicitly mentioned, presents great opportunities as a sustainable solution in efforts to increase agricultural productivity, prevent environmental damage, and achieve national food self-sufficiency. We make policy recommendations to integrate biochar as one of the means to achieve increased agricultural yields and realize food self-sufficiency in Indonesia in accordance with RPJMN recommendations.

Table 11. Policy recommendations for biochar governance in Indonesia

Recommendations		Descriptions	Regulations
	**Include biochar in the strategic plan (RENSTRA) of Ministry of Agriculture 2025-2029**	Revise and enter the matrix for the adaptation of biochar as goal indicators in the Ministry of Agriculture's Strategic Plan 2025-2029.	Regulation of the Minister of Agriculture on Strategic Plan 2025-2029 which relates with RPJMN's mission to increase agricultural yields to achieve food self-sufficiency
	**Provide biochar subsidy for farmers**	Revise and add articles related to biochar subsidies in regulations.	Regulation of the Minister of Agriculture on Fertilizer Subsidy No. 1 2024.
	**Biochar adoption in agriculture to increase yield**	Revise and add the use of biochar in horticultural cultivation practices in article 7 and related derivative articles.	Regulation of Ministry Of Agriculture No. 22/2021 on Good Horticultural Practices.

Recommendations		Descriptions	Regulations
	**Include biochar as a part of organic agriculture practices**	Revise the annex in the Minister of Agriculture's regulation No. 64/2013, and include biochar as one of the soil amendment materials.	Regulation of Minister of Agriculture No. 64/2013 on Organic Farming System.
	**Recognize biochar as a soil improver**	Revise the annexes in the Minister of Agriculture's regulation No. 70/2011, and establish standards for biochar as a recognized soil improver.	Regulation of Minister of Agriculture No 70/2011 on Organic Fertilizers, Biofertilizers, and Soil Improvers.

Recommendations		Descriptions	Regulations
	**Provide agricultural extension services to farmers on the use and benefits of biochar**	Revise and add clauses to make biochar as one of the mandatory materials in agricultural extension services in Indonesia.	Presidential Regulation No. 35/2022 concerning Strengthening the Function of Agricultural Extension.
	**Provide comprehensive public information on biochar by the government**	Revise Article 12 to include biochar as mandatory public information that must be made available by the Ministry of Agriculture.	Regulation of Minister of Agriculture No. 32/2011 on Public Information Management and Services within the Ministry of Agriculture.
	**Implement biochar to conserve critical land**	Revise Articles 16, 17 and 18 to incorporate biochar as one of essential tools in soil conservation techniques in Indonesia.	Regulation of Minister of Environment and Forestry No. 23/2021 on Forest and Land Rehabilitation.

Recommendations		Descriptions	Regulations
	**Incorporate biochar into carbon trading practices in Indonesia**	Establish a new Regulation of the Minister of Environment and Forestry on Carbon Trading in the Agricultural Sector, based on the benchmark from the minister's regulation on Carbon Trading in the Forestry Sector.	Regulation of the Minister of Environment and Forestry on Carbon Trading in the Agricultural Sector

Section 6: The Future of Biochar in Indonesia

The future use of biochar has great economic and environmental potential in Indonesia. The Indonesian government has a great opportunity to utilize biochar as a tool to achieve Indonesia's NDC emission targets and improve the economy in the agricultural sector. The Indonesian government has realistic options to drive national-scale biochar adoption with political will and a structured action plan to drive Indonesia's targets toward a 2045 Golden Indonesia.

Benefits of biochar adoption in Indonesia

Agricultural benefits:

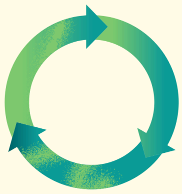
- The potential to increase national crop yields by millions of tons
- The potential to reduce reliance on chemical fertilizers
- The potential to reduce future government spending on fertilizer subsidies

Environmental benefits:

- The potential to reduce the agriculture sector’s contributions in carbon emissions, which accounts for 13% of Indonesia's total GHG emissions;
- Carbon sequestered by biochar can reach millions of tons per year if adopted in the agricultural sector;
- Restores fertility to degraded soil

Figure 19. **The benefits of effective biochar policy governance for Indonesia**

Grow a massive biochar industry and open a biochar market in Indonesia



Increase the potential of circular economy by converting biomass waste into biochar

Increase yield in the agriculture sector

Restore fertility to degraded soils for better agricultural productivity

Reduce greenhouse gas emissions in the agricultural sector

Boost the economic income of both the country and farmers

Reduce dependence on chemical fertilizers

Generate economic income from carbon sales through biochar carbon removal

Increase the competitiveness of Indonesian agricultural products in international markets

Encourage biochar innovation for agricultural resilience and sustainability

Figure 20. Strategic steps for biochar policy design in Indonesia

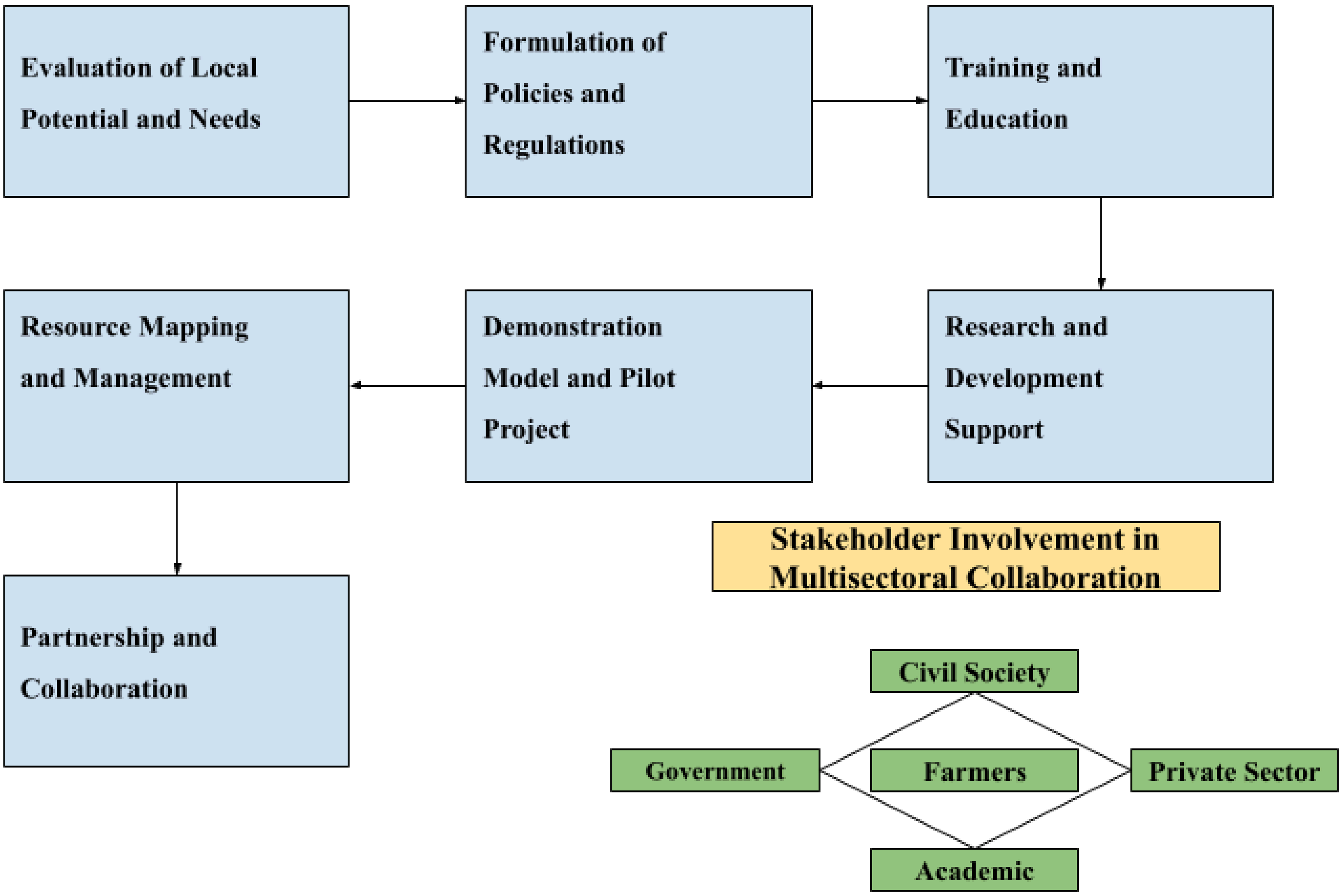


Table 12. Indonesia's biochar governance roadmap

Bold Moves	Immediate Actions	Medium-term Actions (2 years)	Long-term Actions (5 years)	Key Stakeholders
Transform agricultural policy governance	Include biochar in the Ministry of Agriculture's strategic plan (RENSTRA) 2025-2029.	Change agricultural policies and integrate biochar use as one of the good practices in agricultural soil cultivation models in Indonesia.	Reformative changes to Indonesia's agricultural laws with reference to good practices in biochar application.	• Ministry of Agriculture • Coordinating Ministry for Food Affairs • Coordinating Ministry for Economic Affairs • Ministry of Villages, Underdeveloped Regions, and Transmigration • Farmers associations • Private sectors • Related agriculture associations
Encourage biochar application as an integrative solution for agriculture and the environment	Facilitate access to biochar for farmers by offering incentives and providing relevant information through government websites and media.	Revise subsidy and agricultural policies by including biochar in a comprehensive subsidy scheme for the sector.	Establish a new, dedicated agency to oversee and encourage the use of biochar in Indonesia.	• Ministry of Agriculture • Coordinating Ministry for Food Affairs • Ministry of Environment • Ministry of Finance • Ministry of Investment and Downstream Industry • Coordinating Ministry for Economic Affairs • Regional governments • Farmers associations • Private sectors

Bold Moves	Immediate Actions	Medium-term Actions (2 years)	Long-term Actions (5 years)	Key Stakeholders
Promote biochar-related capacity building to key stakeholders	Strengthen the roles and responsibilities of agricultural extension workers by providing them with information and resources on the benefits of biochar for agriculture.	Change policies related to agricultural information and best practices, and the role of agricultural extension workers in Indonesia's large agricultural system	Increased state spending in the agricultural sector that focuses on capacity building and research into sustainable agricultural practices	• Ministry of Agriculture • Regional governments • Farmers associations • Private sectors
Strengthen research and development of biochar benefits	Encourage research on the benefits of biochar by conducting massive-scale trials on various types of land and crops in Indonesia.	Establish a biochar good practice guidebook (application method, biochar content, and others) for the bureaucracy, agricultural assistants and farmers in Indonesia.	Establish standardization for biochar adoption in Indonesia for biochar content, biochar machines, planting mixes and methods, etc.	• Ministry of Agriculture • Coordinating Ministry for Food Affairs • Ministry of National Development Planning • National Research and Innovation Agency • Universities and other academic institutions • Regional governments • Farmers associations • Private sectors

Bold Moves	Immediate Actions	Medium-term Actions (2 years)	Long-term Actions (5 years)	Key Stakeholders
Encourage the local biochar industry to produce quality and competitive products	Encourage easy access and collaboration between private and public sectors in the sustainable agriculture sector to conduct pilots in the context of sustainable agriculture innovation in Indonesia.	Encourage incentive schemes for companies in the sustainable agriculture sector in the form of tax exemptions, and subsidies to access resources that support innovation.	Biochar industry standardization and policy transformation for Sustainable Agriculture Sector industry	• Ministry of Agriculture • Coordinating Ministry for Food Affairs • Ministry of Industry • Ministry of Trade • Farmers associations • Private sectors

Section 7: WasteX - Bina Tani and AdaKarbon Strategy and Action Plan

Table 13. Action plan for advocacy on national biochar adoption

Activities	Outputs	Short-term Outcomes	Long-term Outcomes
White Paper Dissemination	Relevant ministries are aware of and use our white paper as a basis for strategic policy formation for 2025-2029.	The Indonesian government recognized biochar as one of the best practices in agriculture in Indonesia by being included in the Ministry of Agriculture's strategic plan.	The creation of good biochar governance in supporting the biochar industry, sustainable agriculture and economic improvement by farmers.
Site visit to WasteX's partner facility	Provide the good practices of biochar production and implementations for policy makers	Growing awareness of the benefits of biochar for agriculture and the environment to key stakeholders in Indonesia	Implementation of the use of biochar to farmers by national and local governments by providing support for it.

Activities	Outputs	Short-term Outcomes	Long-term Outcomes
Partnership/collaboration meeting for trial/workshop biochar activity with Ministry of Agriculture	Trial/workshop for biochar implementation in crop yields and the implementation of biochar in areas with low soil fertility	Good practices on the benefits of biochar for agriculture and the environment are adopted by the government	Widespread adoption of biochar and development of biochar use policies at national/regional scale.
Biochar Carbon Removal methodology proposal to the National Registry System (SRN, *Sistem Registri Nasional)*	Published methodology to accommodate project owner to register their carbon credits	Initiate biochar carbon credits as legal way to offset emission	Increased number of Biochar carbon credits in Indonesia and also exporting Biochar carbon credits abroad
Public campaigning for good practices of biochar implementation in Indonesia (based on the results of the P4G project for example)	Gained public awareness for biochar benefits in agriculture and environment sector	Expanding public dissemination of biochar use information and support to encourage large-scale biochar adoption	Achieved ease of access to biochar in Indonesia

Activities	Outputs	Short-term Outcomes	Long-term Outcomes
Capacity development for Key stakeholders related to the application and benefits of biochar	Biochar utilization is growing among farmers.	Achieved dissemination of biochar adoption tools to key stakeholders in Indonesia's agriculture sector.	Establishment of standardized guidance on biochar adoption in the agricultural sector
Capacity development for farmers, agricultural extension workers, agricultural offices and farmers' associations, and, government officials related to the application and benefits of biochar	Biochar utilization is growing among farmers.	Achieved dissemination of biochar adoption tools to key stakeholders in Indonesia's agriculture sector.	Establishment of standardized guidance on biochar adoption in the agricultural sector
Technical support for policy development	Establishment of relevant policies to support the use of biochar in Indonesia	The legalization of biochar as a good practice in the agricultural and environmental sectors in Indonesia and the establishment of a biochar subsidy scheme for farmers by the Indonesian government.	Establishment of all supporting regulations for the biochar industry in support of biochar adoption at the national level

Figure 21. Framework for Biochar Adoption on the National Scale

Conclusion

- Biochar has been proven by research and implementation in the field to increase crop yields while reducing fertilizer use and significantly reducing the release of greenhouse gases into the atmosphere.
- As a new innovation in the agricultural sector in Indonesia, biochar answers the challenges of climate change while potentially increasing agricultural yields.
- The low adoption of biochar among farmers in Indonesia requires a solid policy foundation to accelerate the adoption of biochar among farmers. The Ministry of Agriculture plays a strategic role to bring biochar to a more dominant level as a climate change mitigation action as well as an effort to increase agricultural productivity at the national scale.
- The agricultural sector, which contributes 13% of total carbon emissions in Indonesia, is a big challenge for the agricultural sector in order to achieve the National Determined Contribution (NDC) carbon reduction target at the national scale.
- Biochar as an integrative solution can be the answer for the sustainability of agriculture in Indonesia in an effort to increase agricultural yields in Indonesia and reduce carbon emissions in the agricultural sector.

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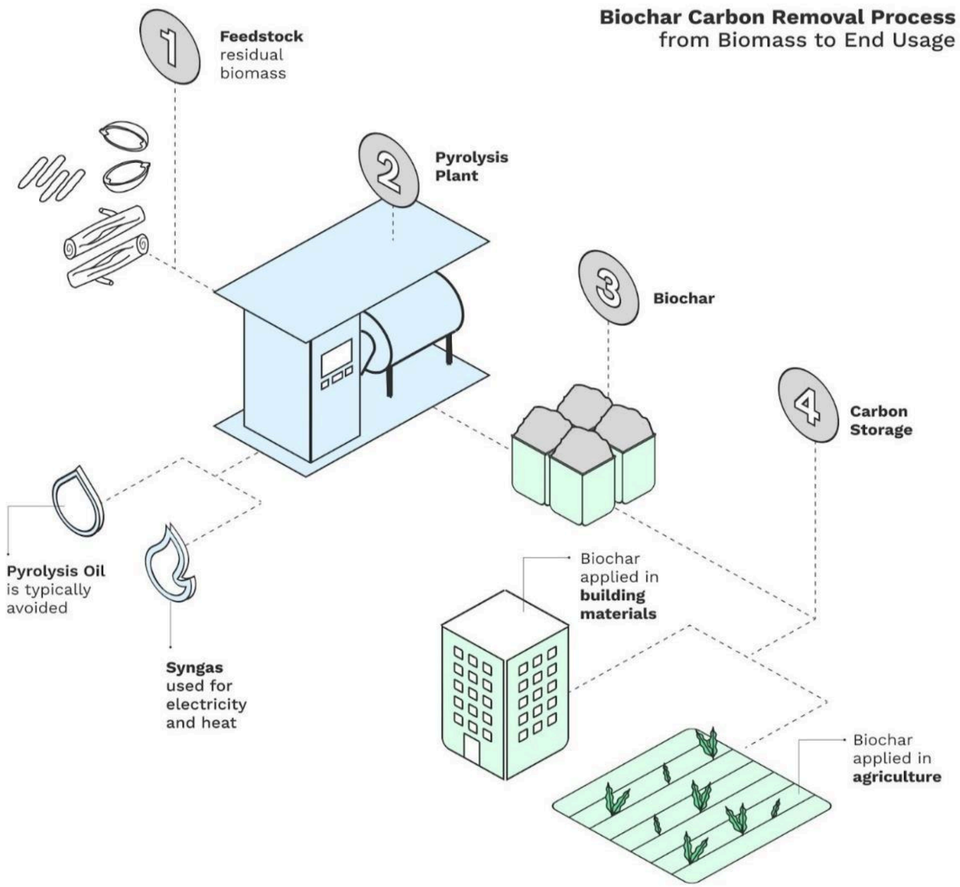
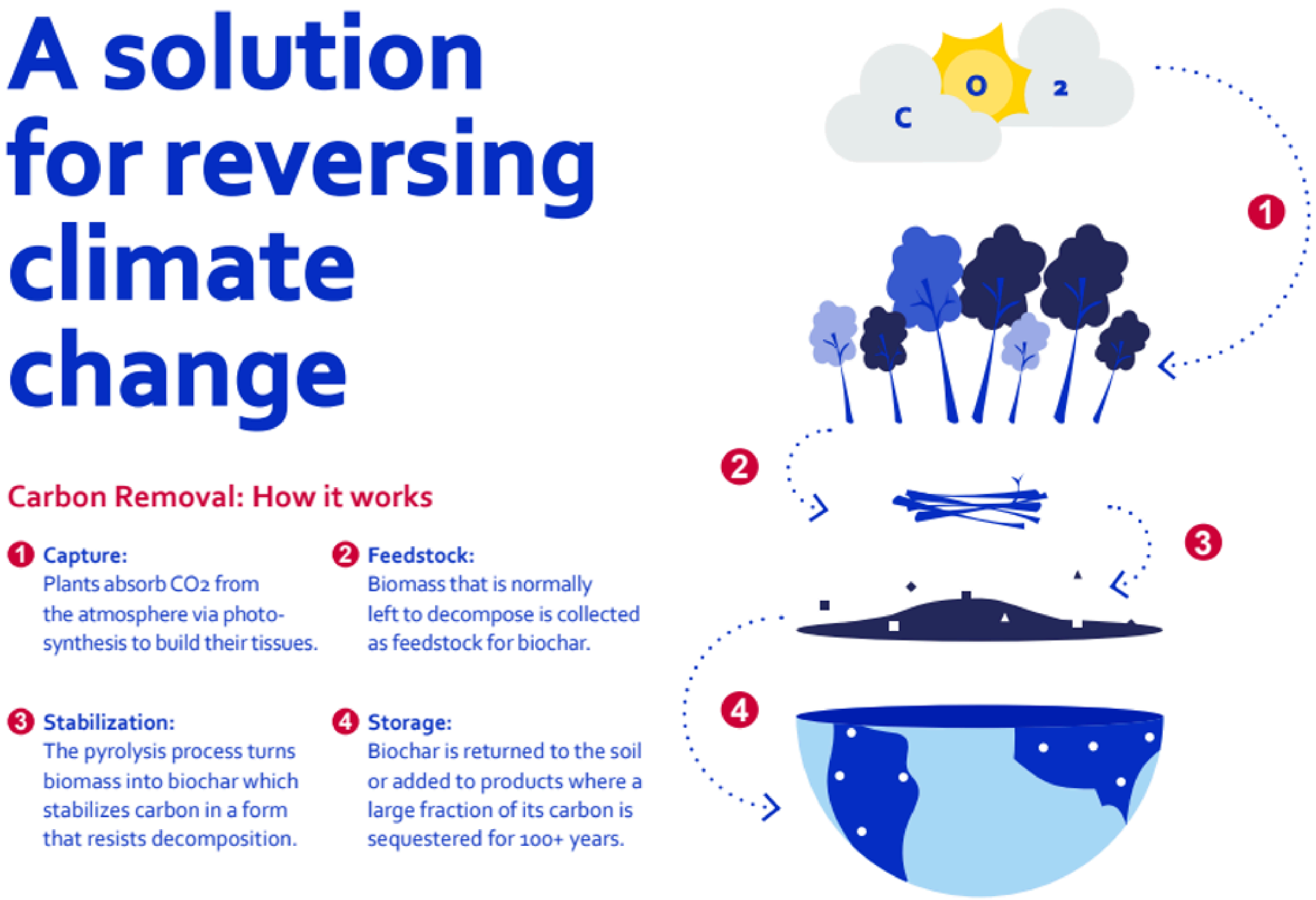
Appendix

1. World Economic Forum: Biochar Carbon Removal process from biomass to end usage



2. How Biochar Carbon Removal works for the environment



3. Full table of comparison Scenario Biochar Adoption for Rice Smallholder in Indonesia (0.5 ha)

Scenario	Planting Area	Planting Cost (USD/year)	Yield Increase (ton/year)	Yield Income (USD/year)	Urea and NPK Fertilizer usage (Kg/year)	GHG Emission (Ton CO2e/year)	Emission reduction (ton/year)	Biochar production (ton/year)	Carbon Capture (ton/year)	Potential Revenue (Yield + Carbon) (USD/year)
Without Biochar	0,5	748.2	5.4	1,439.1	398.3	5.5	0.0	0.0	0.0	1,439.1
With Biochar	0,5	778.6	6.5	1,726.9	298.7	2.4	3.1	1.8	1.6	1,808.7
Difference		-30.4	1.1	287.8	99.6	3.1	-3.1	1.8	1.6	369.6

4. Full table comparison of National Biochar Adoption for Rice Crops for 0%-10%, and 100% adoption rate

Scenario	National Yield Increase (Million ton/year)	National Yield Income (Million USD/year)	Urea and NPK Fertilizer usage (Million ton/year)	GHG Emission (Million Ton CO2e/year)	Emission Reduction (million ton/year)	Biochar Production (Million ton/year)	Carbon Capture (Million ton/year)	Potential Revenue (Yield + Carbon) (Billion USD/year)
Baseline	109.8	29,388	8.1	111.6	0.0	0.0	0.0	29.38
10% adoption rate	112.0	29,976	7.9	105.3	6.3	3.6	3.3	30.14
100% adoption rate	131.8	35,266	6.1	48.3	63.3	35.7	33.4	36.93
Difference 0-10%	2.2	587.8	-0.2	-6.3	6.3	3.6	3.3	0.76

5. Full table comparison Scenario Biochar Adoption for Corn Smallholder in Indonesia (0,5 Ha)

Scenario	Crop	Planting Area	Planting Cost (USD/year)	Yield Increase (ton/year)	Yield Income (USD/year)	Urea and NPK Fertilizer usage (Kg/year)	GHG Emission (ton CO2e/year)	Emission reduction (ton/year)	Biochar production (ton/year)	Carbon Capture (ton/year)	Potential Revenue (Yield + Carbon) (USD/year)
Baseline without Biochar	Corn	0,5	861.3	5.8	2,180.3	801.0	3.8	0.0	0.0	0.0	2,180.3
With Biochar	Corn	0,5	857.9	7.0	2,616.3	600.8	1.3	2.4	1.4	2.4	2,734.1
Difference			3.3	1.2	436.1	200.3	2.4	-2.4	1.4	2.4	553.9

6. Full table comparison of National Biochar Adoption for Corn Crops for 0%-10%, and 100% adoption rate

Scenario	National Yield Increase (million ton/year)	National Yield Income (million USD/year)	Urea and NPK Fertilizer usage (million ton/year)	GHG emission (million ton CO2e/year)	Emission reduction (million ton/year)	Biochar production (million ton/year)	Carbon Capture (million ton/year)	Potential Revenue (yield+carbon credits) (billion USD/year)
Baseline	28.9	10,845	4.0	18.7	0.0	0.0	0.0	10.84
10% adoption rate	29.50	11,062	3.88	17.45	1.21	0.68	1.17	11.12
100% adoption rate	34.7	13,014	3.0	6.6	12.1	6.8	11.7	13.60
Difference 0-10%	0.6	216.9	-0.1	-1.2	1.2	0.7	1.2	0.28

7. National Stakeholder Mapping

Institutions	Issues	Influence	Interest	Expected Results by Stakeholders
Coordinating Ministry for Economic Affairs	Support for biochar adoption for agriculture and biochar incentive scheme for farmers	High	Medium	1. Influencing the other ministry (MoA and MoF) to give subsidies for Biochar 2. Issued Ministerial Regulations for establishment of National Secretariat for Biochar
Coordinating Ministry for Food Affairs	Support biochar adoption for agricultural sector to achieve Indonesia's food security	High	High	1. Conducting economic calculation analysis for biochar adoption to pursue national crop yield increase 2. provide support and support for biochar adoption through policies on the use and strengthening of biochar among farmers
Ministry of Agriculture	Biochar Adoption for Agriculture	High	High	1. Biochar is included in the Ministry of Agriculture's strategic plan 2025-2029 2. Biochar considered as a soil amendment medium for the agricultural sector in Indonesia; 3. Carbonizer machine considered as one of Agriculture machine in Indonesia
Ministry of Environment	Biochar adoption for land rehabilitations and for GHG Emission reduction for Agriculture	High	Medium	1. Issued MoEF Regulations revision on land rehabilitation and add biochar as a one of the solutions 2. Issued MoEF Regulations for Biochar Carbon Removal guidance and standard for Indonesia Carbon Trade
Ministry of Industry	Considered Biochar machine as an agriculture machine in Indonesia	High	Low	1. Supporting for standardization machine carbonizer for agriculture with ISO revision

Ministry of Trade	Biochar subsidy governance and practices for agriculture	High	Low	1. Once government considered biochar subsidy, MoT need to create a Ministerial regulation for governance and practices in the context of procurement and purchase biochar in Indonesia
Ministry of Home Affairs	Monitoring and evaluation regional government to adopt biochar as a agriculture practices in Indonesia	Low	Low	1. Released Implementation and technical guidelines for local governments for the adoption and implementation of biochar in the agricultural sector.
Ministry of Villages, Underdeveloped Regions, and Transmigration	Supporting Villages government to utilizing Village Fund to subsidy/buying biochar or carbonizer machine to improve yield and GHG Emission in Village level	High	High	1. Revise the rules for the use of village funds and include the development of a sustainable agriculture sector as one of the main activities that must be allocated by village governments in the use of village funds.
National Food Agency	Revise the regulations regarding of Food Organic and non-organic standard and included biochar as a part of it	Medium	Medium	1. support to consider Biochar as one of the sustainable good practices that can be applied in the framework of organic product designation in the food sector.
Regional Government (Provinces and Regencies or Cities)	Increase agricultural productivity at the regional level; implement sustainable agricultural practices in the region and facilitate farmers in accessing biochar resources	High	High	1. Biochar adoption programs are included in the annual work plans of agriculture offices at the provincial and district levels in Indonesia.
Institutions	**Issues**	**Influence**	**Interests**	**Expected Results by Stakeholders**
Farmers Associations	Access to biochar; ease of information related to the use	Medium	High	1. Expansion of biochar use among farmers

	of biochar in the agricultural sector; increased crop productivity			2. Encouragement to the government to scale up biochar adoption among farmers with subsidies
Biochar Associations	Market access for biochar and carbon credit	Medium	High	1. Support for biochar implementations to open the market access in Indonesia 2. Support for biochar carbon mechanism in Indonesia
Private Sectors	Market access for biochar carbon credit in Indonesia Carbon Trade; Implementation of green economy in agriculture, plantation and livestock industry sectors	High	High	1. Support Biochar adoption in Indonesia 2. Biochar Carbon Removal included in Sistem Registri Nasional and Carbon Trading in Indonesia 3. Support wide implementation of biochar and production in Plantations/agriculture business.

8. Internal Expected Contribution and Strategy for National Biochar Adoption

Organizations	Expected Contributions	Strategy
WasteX	• Provide technical support for policy development • Support for influencing policy makers to develop agriculture policy • Provide facility for study case and trial for government officials and farmers • Provide Biochar access for smallholders • Provide good practices and success stories in biochar implementation • Provide carbonizer machine for sustainable agriculture business entity	• Open and maintain good relationship with government officials and farmers association/smallholders • Produce monthly newsletter releases related to biochar good practices • Provide space for cooperation with government, farmers or associations who wish to partner in biochar adoption. • Bilateral meeting activity • Workshop with key stakeholder • Support for guidance book for biochar implementation • Provide field visit • Conduct consultation/multistakeholder forum/correspondence with key stakeholder • Create coalition for biochar adoption with other interested parties
Bina Tani	• Provide technical support for policy development • Support for influencing policy makers to develop agriculture policy • Provide field assistance for farmers/association	• Updating biochar material for advocacy purposes • Conduct Multistakeholder forum/dialogue/bilateral meeting/consultation meeting with government official, academic and association

	• Provide good practices and success stories in biochar implementation • Provide module/guidance book for biochar implementation to farmers • Provide advocacy material for biochar • More engagement activity with officials and other stakeholder for biochar adoption purposed • Conduct more communication for establish alliance/coalition for biochar adoption • Released policy paper on biochar implementation and benefit for sustainable agriculture	• Monthly newsletter of sustainable agriculture in biochar related issues • Initiate to establish alliance for biochar adoption with other stakeholder • Create forum/event for biochar related discussion/implementation • conduct workshop and capacity development for government officials and other interested party
AdaKarbon	• Provide technical support for carbon policy development • Support for influencing policy makers to develop carbon and climate change policy • Provide field assistance for farmers/association • Provide good practices and success stories in biochar implementation • Provide advocacy material for biochar adoption • More engagement activity with officials and other stakeholder for biochar adoption purposed • Conduct more communication for establish alliance/coalition for biochar adoption	• Conduct bilateral meeting with government official • Released guidance book/policy paper for biochar carbon removal in Indonesia • Advocacy for carbon removal methodology for the SRN (Sistem Registri Nasional) • Provide biochar as a carbon removal advocacy material • Provide Monthly newsletter • Create forum/event with biochar or carbon as a main topic • conduct workshop and capacity development for key stakeholder

	• Released policy paper on biochar implementation and benefit for sustainable environment	• Consultation forum with government with biochar as a carbon removal topic

9. Indonesia flood and drought area in rice crop 2021 - 2023