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Biodiversity and Climate-Smart Agriculture: A Review of Conservation and Environmental Aspects of PUSAKA BUMI Program

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Abstract. Mangoes are a widely cultivated commodity, integral to the identity and economy of Indramayu Regency. However, mango cultivation faces significant challenges, primarily due to climate change and soil degradation. These two factors negatively affect the quantity and quality of mango production, threatening the sustainability of local agriculture and farmers' livelihoods. In response, Pertamina Patra Niaga Integrated Terminal Balongan, in collaboration with the Salam Tani Farmer Group in Sliyeg Lor Village, initiated the Biodiversity Cultivation Sanctuary Center (Pusat Suaka Budidaya Keanekaragaman Hayati/PUSAKA BUMI) program as an effort to conserve the local Indramayu mango (*Mangifera indica*) varieties. Using a qualitative descriptive approach, this paper aims to explain the biodiversity conservation efforts, particularly for local mango varieties in Indramayu Regency, through the PUSAKA BUMI Program and its environmental impacts. The results show that the local mango conservation efforts are manifested in two ways. First, the implementation of Climate-Smart Agriculture (CSA) involves developing a botanical garden equipped with a greenhouse and smart farming systems to create environmental adaptations to climate change. Second, the Bio-Retra innovation utilizes agricultural biomass residues to produce biochar and liquid organic fertilizer as a replacement for chemical fertilizers to restore soil health.

Keywords: *Mango Conservation; Climate-Smart Agriculture; Biochar.*

A. INTRODUCTION

The mango is a renowned and exotic commodity produced in almost all regions of Indonesia, one of which is Indramayu Regency. It is also identified as one of the fruit commodities with the highest comparative and competitive advantage in the world (Pradipta & Firdaus, 2014). Indramayu Regency and the mango are two inseparable entities. The mango has become a leading commodity and the identity of Indramayu, widely known as one of the largest mango producers in Indonesia (Rasmikayati, Elfadina, Kusumo, Saefudin, & Supriyadi, 2020).

However, the growth of mango farming in Indramayu faces significant challenges. Numerous technical and non-technical obstacles often result in unstable production and low-quality mangoes (Sulistyowati, Natawidjaja, & Saidah, 2013). These challenges include production factors, price/market risks, human risks, financial risks, and institutional risks. All these sources of risk have the potential to disrupt the production process at the farmer level, affecting the entire agribusiness process and ultimately impacting mango farmers' incomes (Pedekawati, Karyani, & Sulistyowati, 2017). These various risks, when traced, can be attributed to two major factors: climate change and soil quality degradation, both of which lead to a decline in agricultural production quantity and quality.

The massive climate change occurring globally since the late 20th century is indicated to be a cause of increased carbon dioxide (CO_2) levels in the atmosphere. The impacts of climate change can threaten ecosystems and potentially cause sea-level rise, floods, and droughts (Santos & Bakhshoodeh, 2021). Human daily activities unwittingly contribute to increased carbon emissions, such as the use of motor vehicle fuels, coal, petroleum, and natural gas. These routine activities produce hazardous gases such as carbon dioxide (CO2), water vapor (H_2O), Chloro Fluoro Carbon (CFC), Nitrous Oxide (N_2O), Methane (CH_4), and Ozone (O_3), commonly known as greenhouse gases, leading to global warming (Ainurrohmah & Sudarti, 2022). According to a report from the UN Environment Programme (UNEP), the current increase in Earth's temperature exceeds the global warming limit target set during the 2015 Paris Agreement. The commitment was to limit global warming to 1.5-2°C, but it currently shows an increase of 2.8°C by the end of this century. If this continues, in the long term, it will only reduce the temperature rise to 2.4 – 2.6°C (United Nations Environment Programme, 2022).

Climate change remains a critical global issue. This concern is well-founded, as climate change significantly disrupts human life, including the agrarian sector. Climate anomalies such as changes in rainfall intensity and patterns, temperature increases, droughts, floods, and increased intensity of pest and disease attacks are symptoms of climate change that can impact agricultural productivity, particularly food crops (Suryana, 2014).

For example, in China, climate change, particularly in temperature and wind speed elements, has a significant negative impact on agricultural productivity. Heterogeneity tests show that climate change significantly hampers the growth of agricultural productivity in rice planting areas (Bai, Ye, Yang, & Wang, 2022). In Indonesia, climate fluctuations, such as temperature changes, have a substantial impact on the decline in mango productivity in Indramayu, with a determination coefficient of 0.67 (Triani & Ariffin, 2019). Meanwhile in Jember, which has coastal agricultural characteristics like as Indramayu, changes in rainfall, temperature, and sea-level rise have reduced rice agricultural productivity (Hidayatullah & Aulia, 2019).

The general condition regarding the impact of climate change in Indonesia can be more clearly seen through the ENSO (El Niño Southern Oscillation) indicator, which consists of El Niño and La Niña. El Niño, accompanied by a decrease in rainfall, has a greater impact on rice and corn production. In contrast, La Niña, which is accompanied by an increase in rainfall, has a greater impact on soybean production. Among these three food commodities, El Niño has a greater impact on food production in most regions of Indonesia compared to La Niña (Malau, Rambe, Ulya, & Purba, 2023).

Climate change, which impacts the decline in agricultural productivity, requires serious attention from agricultural stakeholders in Indramayu Regency, especially in the mango cultivation sector. This is highly justified considering that Indramayu is one of the main mango-producing centers in West Java Province (Rasmikayati, Elfadina, Kusumo, Saefudin, & Supriyadi, 2020), while 67% of mango productivity levels are influenced by climate and weather factors (Triani & Ariffin, 2019).

Besides climate change, another inhibiting factor in mango cultivation in Indramayu is soil quality degradation, partly caused by the excessive use of chemical fertilizers. Issues with environmentally unfriendly fertilizers and high emissions from waste decomposition are problems in the agricultural and plant cultivation world. The use of chemical fertilizers such as NPK causes adverse effects, starting with soil damage, environmental pollution, human health disturbances, and the potential to kill soil microorganisms (Li, et al., 2020).

Land degradation has become one of the biggest environmental challenges faced by farming communities today. Therefore, understanding this land crisis is necessary. Land degradation is understood as a negative trend in land conditions, caused directly or indirectly by human activities, resulting in the loss of at least one of the following aspects: biological productivity, ecological integrity, or value for humans (Pravalie, 2021). The process of land degradation is marked by changes in physical, chemical, and biological properties, making the land critical (Rusdiyana, Nurwahyunani, & Marianti, 2021).

Climate change and land degradation significantly reduce agricultural land productivity, from global/continental scales to regional/national or local scales. These two issues also contribute to the intensification of socio-economic disparities and social inequalities, resulting from land disturbances (Pravalie, 2021). The adverse impact of these two problems in the context of mango cultivation in Indramayu is the threat to biodiversity, particularly the existence of local mango varieties as the region's superior germplasm. Therefore, it is important to manage local mango varieties to ensure continuous quality and quantity, prevent extinction, and use them as potential genetic material in plant breeding in Indramayu's germplasm (Laila & Yuliana, 2020)

Unfortunately, climate change cannot be stopped immediately and simply. The most feasible steps humans can take are to adapt to climate and mitigate land quality decline in agricultural processes. Simply put, adaptation is understood as actions to adjust to anticipate the negative real impacts of climate by building anticipation strategies and leveraging advantageous opportunities. One urgent mitigation step is through the conservation of local fruit plants. Conservation efforts are translated as the wise management and utilization of the biosphere to meet the needs of the current and future generations (Wiryono, 2013).

One of the adaptation and mitigation efforts against climate threats and land degradation in the mango agriculture sector in Indramayu is the Biodiversity Cultivation Sanctuary Center (PUSAKA BUMI) Program implemented by Pertamina Integrated Terminal Balongan in collaboration with the Salam Tani Farmers Group in Sliyeg Lor Village. Arising from climate and land issues that threaten local mango varieties, this program represents a conservation effort based on maintenance, breeding or cultivation, research, and recreational prospects on biodiversity, particularly the local mango *(Mangifera indica)* variety of Indramayu.

The PUSAKA BUMI program strives to apply a commitment to conserve local mangoes as a germplasm resource through the development of a botanical garden. These efforts are realized through various means such as the development of greenhouses with smart farming applications and the innovation of mango waste biomass and husk retransformation (Bio-Retra). Based on this description, this paper aims to explain how biodiversity conservation efforts, especially local mango varieties in Indramayu Regency, are conducted by Pertamina Integrated Balongan through the PUSAKA BUMI program and its impact on the environment.

B. LITERATURE REVIEW

1. Conservation of Local Fruit Plants

Native fruit species play a significant role in the daily lives of communities in developing countries due to their potential as sustainable resources. Local fruit plants have great potential to improve economic conditions as a source of income and ensure food security for communities (Suwardi, Navia, Harmawan, Syamsuardi, & Mukhtar, 2020). Therefore, ensuring the existence of native fruit plants amid threats of climate change and declining land capacity is crucial. One of the efforts that can be undertaken is community-based conservation. Community-based conservation of fruit plant species diversity based on their varied uses is an effective method of preserving local plants (Indah, Indriyani, Arumingtyas, & Azrianingsih, 2021).

Conservation represents broad protection from all threats and damage factors, including those from humans, livestock, natural factors, diseases, and other unforeseen causes. From an environmental science perspective, conservation is defined as follows (Christanto, 2014): 1. Efforts towards saving/efficiency (e.g., through energy consumption); 2. Careful management and protection of natural resources and the environment; 3. Management of certain quantities that remain stable throughout chemical reactions or physical transformations; 4. Long-term environmental protection efforts; 5. Management of a natural habitat area to ensure the genetic diversity of species is maintained. Conservation efforts play a significant role in supporting life by maintaining ecological processes, preserving species and ecosystems, and ensuring genetic diversity.

In general, biodiversity conservation can be carried out through two methods: in situ and ex-situ. In situ conservation is the conservation of genetic resources undertaken in the natural habitat of plant or animal species, such as forests or other natural ecosystems. The process of protecting endangered plant or animal species in their natural habitat is commonly known as in situ conservation. Conversely, ex-situ conservation is the relocation of endangered or rare species from their natural habitat to a protected artificial area. Ex-situ conservation is an important alternative strategy when in-situ conservation is not feasible (Ajayi, 2019).

2. Climate-Smart Agriculture (CSA)

Climate change is one of the greatest challenges of our time. Rising temperatures, fluctuating rainfall patterns, and increasingly frequent extreme weather events pose serious threats to food systems. Therefore, more resilient food agricultural systems are required through climate-smart agriculture. CSA emphasizes the crucial synergy between climate change mitigation and adaptation and sustainable agricultural production (FAO, 2022).

Climate-Smart Agriculture (CSA) is an innovative approach based on three pillars: sustainably increasing agricultural productivity and incomes; adapting and building the resilience of agricultural and food systems to climate change; and reducing or avoiding greenhouse gas emissions (FAO, 2021). Additionally, the extensive use of chemical fertilizers and pesticides is considered a threat to health, soil, and ecosystem biodiversity. While nitrogen fertilization is crucial for achieving high yields, excessive use can lead to serious environmental and human health problems. If not absorbed by plants, nitrogen can leach through the soil as nitrate, contaminating surface and groundwater (Liu, Su, Li, Yue, & Gao, 2013). CSA promotes the use of alternative organic fertilization and/or judicious pesticide application to avoid unnecessary use, which can also cause issues related to climate change and food quality (Agrimonti, Lauro, & Visioli, 2020).

The application of modern technology in climate-smart agriculture represents an effort that can be implemented in mitigating and adapting to climate change in the agricultural food sector. Several climate change adaptation technologies can enhance climate resilience in Indonesia’s agricultural sector. Adaptation technologies in agriculture often generate co-benefits in the form of mitigation (Surmaini, Supriatin, & Sarvina, 2023). This aligns with the CSA concept, which is a farming business model that combines and adopts adaptation technologies both on-farm and off-farm to support environmental sustainability while maintaining the primary goal of increasing productivity.

C. METHODS

This study employed a descriptive method utilizing qualitative data. Qualitative descriptive research generates data that describe the who, what, and where of events or experiences from a subjective perspective (Kim, Sefcik, & Bradway, 2016). This method provides clarity regarding the phenomenon being studied and the methods used by the researchers because the data collected remains closely tied to the phenomenon throughout the research process (Doyle, McCabe, Keogh, & Brady, 2020). We collected internal data and documents, conducted focus group discussions with program beneficiaries, performed field observations, and gathered scientific data from research related to the PUSAKA BUMI program. The data were then analyzed and interpreted to explain how the conservation efforts for local mango varieties in Indramayu are carried out through the PUSAKA BUMI program.

D. RESULTS AND DISCUSSION

The Biodiversity Cultivation Sanctuary Center (PUSAKA BUMI) Program is an initiative carried out by PT Pertamina Patra Niaga Integrated Terminal Balongan in collaboration with the Salam Tani Farmer Group in Sliyeg Lor Village. The PUSAKA BUMI Program aims to enhance the unique biodiversity of Indramayu through the development of a Botanical Garden, which encompasses activities such as planting, cultivation, management, and the development of a greenhouse area utilizing smart farming technology. Smart farming technology aims to increase crop productivity through the control of nutrients, humidity, fertilization, and irrigation using mechanisms such as the water drip system, fertigation installations, and automatic farming. The PUSAKA BUMI program is implemented in three stages: program planning, program implementation, and the application of biochar innovation.

1. Program Planning Stage

The idea of conserving local mango varieties arose from concerns over the reduction of green space and open land in the Indramayu Regency. Given this situation, conservation efforts are needed that encompass activities including maintenance, breeding or cultivation, research, and recreational prospects for biodiversity, especially the local mango varieties of Indramayu. As a new program, PUSAKA BUMI is a pioneering effort not previously found in similar industries. Since 2022, the PUSAKA BUMI program has focused on developing smart farming systems in greenhouses for local mango commodity development.

The Coordination Meeting for the Pusaka Bumi/Biodiversity IT Balongan Program Plan was held on March 18, 2023, with the main discussion points being the design of greenhouse efficiency for the Pusaka Bumi Program. The follow-up plan from this activity included improvements to the water drip system for automatic farming, updates to application-based automatic farming, and the development of the smart farming system.

Figure 1. The Green House

Source: Internal Document (2024)

On June 15, 2023, the PUSAKA BUMI program was implemented in Blok Senibah, Sliyeg Lor Village, Sliyeg District, Indramayu Regency. The activities were attended by PT Pertamina Patra Niaga Integrated Terminal Balongan, UPTD Food Security and Agriculture Jatibarang, and the Salam Tani Farmer Group.

2. Program Implementation Stage

In addition to focusing on developing smart farming systems in the greenhouse for local mango commodity development, the program also aims to enhance community capacity. This is achieved through training and assistance in producing diversified mango products. The PUSAKA BUMI program emphasizes the development of a Botanical Garden as an effort to collect, maintain, and breed various plant species to develop new habitats or varieties. The development of the Botanical Garden uses the Smart Farming concept by creating a production garden with intercropping systems for the main crop of Fruit Plants in Pots (Tanaman Buah Dalam Pot/Tabulampot) in response to the decline in green open space. The greenhouse development location with the water drip system is in Blok Senibah, Sliyeg Lor Village, Sliyeg

District, PUSAKA BUMI. The greenhouse area development focuses on cultivating new varieties to preserve the unique biodiversity of Indramayu.

3. Enrichment of Local Fruit Plants

The implementation period for the biodiversity program activities under the Pusat PUSAKA BUMI Program was from July to December 2023. In 2023, the PUSAKA BUMI Program successfully planted 120 horticultural trees, which included:

No	Plant Type	Quantity
1	Miyazaki Mango Variety	30 Trees
2	Grafted Mango	30 Trees
3	Water Apple	15 Trees
4	Guava	15 Trees
5	Melon	15 Plants
6	Chili	15 Plants

(Source: Internal Document, 2024)

The harvest from this program was directly utilized by community groups as food commodities. The effort to plant 120 trees has motivated the company and the beneficiary communities to continue striving to preserve and protect biodiversity. The PUSAKA BUMI area has become an ecotourism destination for the community, promoting local tourism by offering fruit-picking tours and selling fruit commodities.

4. Development of the Smart Farming System

The conservation efforts carried out through the PUSAKA BUMI program involved developing a greenhouse area with a smart farming system. This system aims to enhance plant productivity through nutrient control, moisture control, fertilization, and irrigation using water drip systems, fertigation installations, and automatic farming. The construction of the greenhouse area focused on cultivating new mango varieties as a measure to preserve the unique biodiversity of Indramayu.

The implementation of Smart Farming combines IoT (Internet of Things) with the water drip system for plants. The development of agricultural engineering technology using IoT has a significant impact on the productivity of plants and gardens. With the application of IoT, harvests can be planned by adjusting the moisture and nutrients provided.

The creation of fertigation installations for nutrient and moisture fulfillment is influenced by the availability of water as its main requirement. Therefore, it is necessary to develop a well-functioning fertigation installation to optimize plant development while considering water conservation. For this reason, drip irrigation was chosen for implementation in the Botanical Garden greenhouse.

Capacity Development: the PUSAKA BUMI program not only focuses on fruit commodities but also pays attention to the development of human resources. One of the activities carried out is the planting of rare plants to foster better cross-sector collaboration.

Development of Certified Gardens: one key to success in conservation efforts is the emergence of a new generation. Therefore, the development of the Botanical Garden is not limited to cultivating local plant varieties but also involves legalizing the varieties being developed. Hence, certified garden development is conducted to achieve High-Value Trees (HVT) status for the plant varieties.

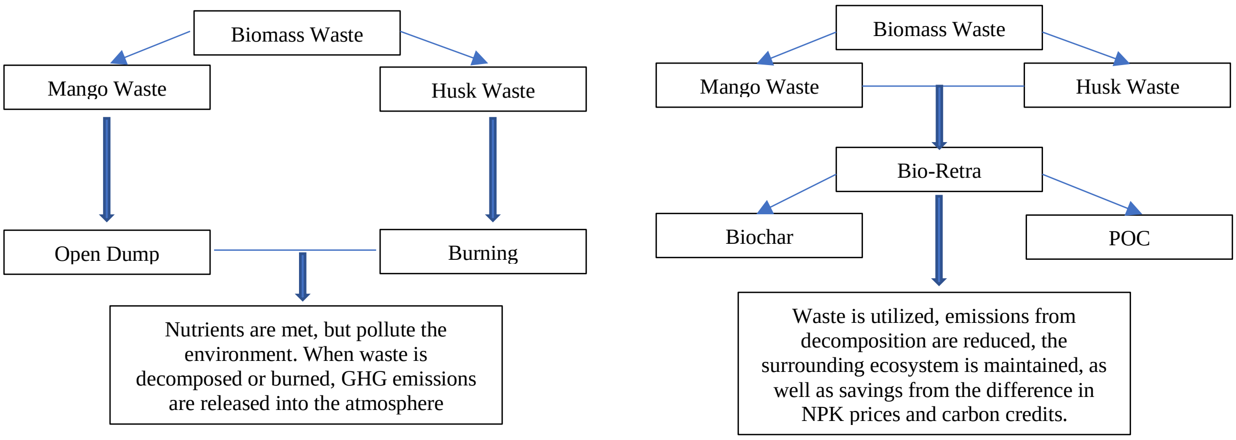
5. Bio-Retra Innovation

Maintaining the environment and reusing available resources is a commitment of PT Pertamina IT Balongan to protect biodiversity. In response, PT Pertamina Patra Niaga IT Balongan, along with the community of Sliyeg Lor Village (represented by the Salam Tani Group), strives to utilize waste materials to meet the nutritional needs of mangoes with minimal environmental impact. This effort is embodied in the Biomass Retransformation Program (Bio-Retra), which transforms biomass waste such as husks and mango seed shells into biochar, while other parts of the mango waste are converted into Liquid Organic Fertilizer (POC).

Biochar, known as a "soil enhancer," improves pH, soil friability, and water porosity, and enriches the soil by increasing its nutrient content and water retention, thereby creating a favorable ecosystem for soil microorganisms. POC complements this by providing various nutrients and beneficial microorganisms for plants. This program aligns with Sustainable Development Goals (SDGs) number 7 on renewable energy, number 13 on climate action, and numbers 14 and 15 on life below water and life on land, respectively.

The innovation development is driven by the suboptimal cultivation of mangoes and the abundance of biomass waste, including husks, seed shells, and other mango residues. Suboptimal mango cultivation limits the potential and benefits of mangoes, while biomass waste has the potential to release greenhouse gases (GHGs) such as CO_2, CH_4, and N_2O, as well as other pollutants, through natural decomposition or combustion.

The Bio-Retra program addresses both issues simultaneously by converting biomass waste into biochar and POC. This involves the re-transformation of mango seed shells and husks into biochar through complete combustion (pyrolysis) and other mango waste into Liquid Organic Fertilizers (POC). Before the program, mango and husk biomass waste was unmanaged, often disposed of through open dumping or burning. Mango cultivation relied on chemical fertilizers, which had a negative impact on the environment. After the implementation of Bio-Retra, the waste is utilized to produce biochar and POC, thereby meeting soil and mango nutrient needs without causing adverse environmental effects.



Scheme Before Program **Scheme After Program**

Figure 2. Scheme Program

The threat of losing local plant varieties due to climate change and land degradation has prompted Pertamina Patra Niaga Integrated Terminal Balongan to undertake conservation efforts for the local Indramayu mango as part of its ex-situ preservation of genetic resources through the PUSAKA BUMI program. Broadly, there are two main initiatives.

First, the adaptation to climate change, which affects the quality and quantity of agricultural yields, is addressed by developing the Botanic Garden as a manifestation of the Climate-Smart Agriculture (CSA) concept. The CSA concept in the Botanic Garden is implemented through mango cultivation inside greenhouses equipped with drip irrigation systems controlled automatically using the Internet of Things (IoT). The use of greenhouses offers advantages over open-field farming, such as reduced evaporation of water and soil nutrients, anticipation of pest attacks leading to healthier plants, and improved health, growth, and productivity of the plants. The IoT-controlled drip irrigation system also provides the benefit of water savings for plant watering.

The development of the Botanic Garden in the PUSAKA BUMI program has positively impacted the environment. According to a sustainability compass analysis, this program has influenced social and environmental aspects. Socially, it has formed a horticultural farming group capable of applying new methods in mango cultivation. Environmentally, the program has successfully transformed 3,000 m² of open land into green open space for modern agricultural development.

Second, efforts to restore the quality of degraded land due to excessive use of chemical fertilizers have been made through the creation of the Biomass Retransformation Innovation (Bio-Retra). This innovation aims to process biomass waste, which is the residue of agricultural processes, into biochar and liquid organic fertilizer. These products substitute the chemical fertilizers commonly used by farmers and aim to restore the health and quality of the agricultural soil for mangoes in Indramayu. In the first year of Bio-Retra implementation, this innovation has positively impacted the environment by utilizing 100 kg of mango waste and 70 kg of husk waste. The program also successfully replaced NPK chemical fertilizers, saving a total cost of IDR 10,000,000 per year. Additionally, the Bio-Retra innovation saves costs calculated from the difference in the replacement of chemical fertilizers with POC and biochar, as well as the carbon price that the company would otherwise incur if burning or decomposition occurred. The efficiency from the Bio-Retra program amounted to IDR 7,350,724 in 2023.

6. **Community-Based Conservation**

PT Pertamina Patra Niaga Integrated Terminal Balongan has begun implementing community-based conservation best practices to promote the preservation of biodiversity and ensure the sustainability of healthy ecosystems. In practice, the conservation efforts by PT Pertamina Patra Niaga IT Balongan cannot operate in isolation; they require collaboration with multiple stakeholders, including the UPTD Ketahanan Pangan dan Pertanian Jatibarang, the Salam Tani Farmers Group, and the residents of Sliyeg Lor Village. Each party shares a common goal: to develop the conservation of local fruit plants and to enhance the economic well-being of farmers.

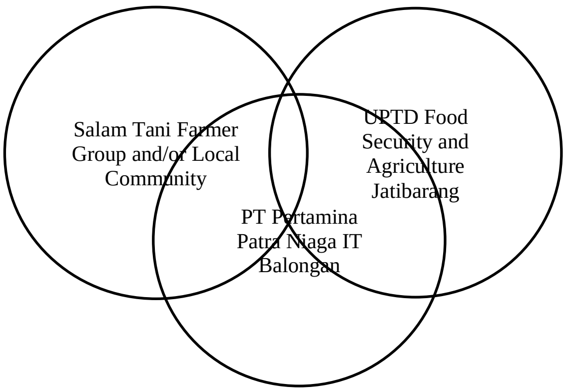


Figure 3. Multi-Stakeholder Partnership in the PUSAKA BUMI Program

The detrimental threats to environmental quality due to climate change and global warming have heightened public concern regarding the resilience of Indramayu's local flagship commodities. This is especially critical in the context of the declining quality of green open spaces, which directly impacts biodiversity reduction. The activities undertaken through the PUSAKA BUMI program aim to educate and train the community to actively maintain the distinctive local mango commodities from their region.

PT Pertamina Patra Niaga Integrated Terminal Balongan not only focuses on empowering the cultivation of local mango varieties but also on educating the community.

Human resource capacity development is a primary focus of the PUSAKA BUMI program. Ultimately, the community will inherit the program's sustainability. The independence of the community in conserving local plants is an unavoidable goal for the success of the PUSAKA BUMI program.

E. CONCLUSION

The PUSAKA BUMI program, implemented by PT Pertamina IT Balongan for the conservation of Indramayu's local mango plants, has proven successful in various conservation and environmental aspects. By applying Climate-Smart Agriculture (CSA) approaches, such as developing a botanic garden equipped with a greenhouse and smart farming systems, the program has created environmental adaptations to climate change that support the optimal growth and preservation of mango plants. The use of smart farming technology not only increases efficiency in plant management but also helps maintain environmental sustainability. PUSAKA BUMI bring a positive impact on climate change adaptation and mitigation by enhancing resources use efficiency, pesticide control, and reducing carbon footprints through the application of advanced technologies. The use of IoT facilitates improved management of climate variability, thereby enhancing crop resilience and reducing the environmental impact of agricultural practices.

Moreover, the innovative re-transformation of mango waste biomass and husks to restore soil fertility demonstrates a commitment to sustainable resource utilization. By using organic waste to enhance soil fertility, the program not only reduces waste production but also supports more productive and environmentally friendly agriculture. Overall, the success of the PUSAKA BUMI program reflects the importance of a holistic approach to local plant conservation and sustainable environmental management. It also serves as an example of how industry can positively contribute to biodiversity preservation and environmental resilience in local areas by involving the community directly.

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