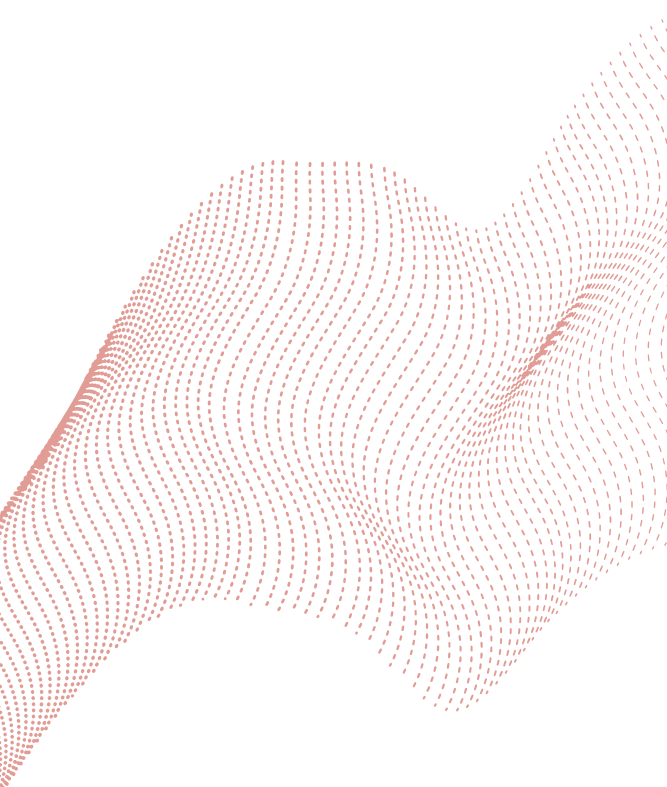


A MARKET STUDY ON BIODEGRADABLE PLASTIC MULCHING FILM AND PLASTIC BAGS





A Market Study on Biodegradable Plastic Mulching Film and Plastic Bags

This study is a collaborative effort between the Resilience Development Initiative (RDI) and iDE Cambodia as a part of the Climate Smart Commercial Horticulture Cambodia (CSmart) project in order to significantly and sustainably increase climate change resilience, farm and food safety, profitability, and market system support for small-scale commercial and semi-commercial horticulture farmers in northwestern Cambodia, including Siem Reap, Banteay Meanchey, and Oddar Meanchey provinces.

Prepared by Resilience Development Initiative (RDI) Team:

Dr. Elisabeth Rianawati

Yoshua Situmorang

Maya Larasati B.Sc

Rifqi Hakim Dewanto B.Sc

This study is made possible by the generous support of the New Zealand Aid Programme.

The view from the report is the responsibility of the RDI team and does not reflect the views of iDE and the New Zealand Aid Programme.



Summary

Over decades of development in Cambodia, horticulture has played a critical role in contributing to the economic sector. The quality and quantity of crop yield have improved tremendously with the rise of technology and agriculture inputs such as premium seeds, fertiliser, and irrigation systems. Along with that, plastic usage in the horticulture sector is also increasing, primarily from using plastic mulch and plastic bags for wrapping agricultural products. However, one of the main problems is that horticulture plastic waste is never completely removed. Instead, it ends up staying in the fields, water bodies, and even buried in the soil. Over time, the plastic breaks down into smaller pieces and can find its way into underground water or, in the worst case, when burned, release harmful chemicals into the air. Some companies are thinking about ways to produce compostable plastic mulch. Still, these products need to be imported and are currently too expensive for widespread adoption within the agricultural sector of Cambodia. Therefore, this market study analyses the possibility of substituting conventional plastic mulch for Cambodia by identifying the market profile, character, and size, and developing possible recommendations.

Based on our research, we found that plastic mulch, dripline, and plastic nets are the most intensely used plastic products in agriculture activities, whereas plastic bags are widely used across the country. As much as 98% of surveyed farmers know plastic mulch, and 67% use plastic mulch. On average, these farmers positively perceive plastic mulch and are willing to continue using it due to its proven benefit in reducing water usage and keeping the soil moist, as well as preventing weed growth. From the market estimation, Cambodia has US\$44 million of the total available market for agricultural plastic mulch, and the serviceable available market is US\$29.5 million. With an estimation of a 10% obtain ratio, the potential market for alternative plastic mulch is US\$2.95 million annually.



The factors that influence farmers' willingness to change their waste management practices include their awareness of environmental issues and their desire to comply with government regulations. However, the lack of easily accessible alternatives and the economic considerations play a significant role in their decision-making process, as farmers prioritise economic factors when it comes to using plastic mulch. To further advance the substitution of biodegradable plastic, strong environmental awareness in the government and the public needs to be developed, and then mainstreaming biodegradable plastic to the farmers.

To promote the application of biodegradable plastic in horticulture, it is crucial to raise environmental awareness among the government and the public. Implementing policies that provide incentives for biodegradable plastic production and imposing extended producer responsibility (EPR) for plastic manufacturers can help reduce prices and encourage sustainable practices. Additionally, fostering a niche customer base of early adopter farmers can influence wider adoption. Standardising biodegradable product certifications is essential to establish consistent expectations and trust among consumers, which can be achieved by developing specific standards aligned with organisations like American Society for Testing Materials (ASTM).

Introduction to this Study

This market study is the initiative of iDE Cambodia to understand the use and subsequent impact of agricultural plastic in Cambodia. The study was done with the support of Resilience Development Initiative (RDI). The project assessed the behavioural usage of plastic and its agricultural management, including a market study of its alternative potential conducted in five Cambodian provinces: Battambang, Kandal, Oddar Meanchey, Banteay Meanchey and Siem Reap.



The purpose of this study is to understand the market size of biodegradable plastic,¹ which include plastic mulching and plastic bags. Plastic mulch is the centre of this study since our findings show plastic mulch is the most plastic used in horticulture. Plastic products have been used extensively in the horticulture sector in Cambodia due to their versatility. However, the use of plastic products in horticulture also contributes to plastic pollution and waste in agriculture. Therefore, there is a need to promote sustainable farming practices, reduce plastic usage in horticulture or replace plastic products with an environmentally friendly material such as compostable plastic or bioplastic. This practice can only be achieved through the participation of the private sector involved in the plastic product supply chain (i.e. manufacturer, wholesaler, distributor and retail). As such, this report aims to provide related information for the private sector to contribute to biodegradable plastic production.

The first part of this market assessment report explains the introduction to plastics in a horticulture setting. The second part provides information about the alternatives to horticulture plastic products. The next part is about the trend of plastic products globally and in Cambodia's horticulture sector, both conventional and biodegradable plastics. The fourth part explains the consumer's demography and perception from related stakeholders on both conventional and biodegradable plastic products. The stakeholders interviewed to provide related information were plastic suppliers, distributors, plastic recyclers and upcyclers. The information is then summarised in the conclusion section, and recommendations are drawn that can be made by stakeholders in the future. This report is designed to help a company understand the need and demand for biodegradable plastic products in the market.

¹ Biodegradable plastics have the characteristic to disintegrate when exposed to naturally occurring bacteria in the soil; biodegradable can be constituted from bio-based and petroleum-based. Biobased plastic or bioplastic is made from non-petroleum biological resources but can also have a non-biodegradable characteristic. The most ideal type of plastic is biodegradable or compostable plastic that can degrade in the soil to prevent plastic build-up (micro and macro plastic); however, some types of biodegradable plastic are not suitable for horticulture activity that requires the product to be durable.



Introduction to Plastics in Horticulture

In Cambodia, agriculture accounts for 22 per cent of Cambodia's gross domestic product (GDP) and employs about 3 million people, and thus serves as the backbone of Cambodia's economy. Plastic products have played an important role in contributing to the growth of horticulture sectors; they are proven to be able to increase productivity, improving crop yields and quality. They are used to pack seeds, pesticides, and fertilisers, or come in the form of plastic mulching films and irrigation systems.

However, one of the main issues with the inputs used is the waste they generate, particularly plastic. Plastic waste is often not completely removed and can remain in the fields, water bodies, or soil, where it can break down into smaller pieces and enter underground water sources. Burning plastic waste can also release toxic chemicals into the atmosphere. This waste can be harmful to the environment and organisms that consume it. Additionally, plastic waste can take up to 1,000 years to degrade in landfills, leaching potentially toxic substances into the soil and water. There are some studies on the pollution of plastic and solid waste in general and plastic pollution in marine ecosystems. Meanwhile, there is a lack of study regarding agricultural plastics such as mulch, packages, containers, and drip lines.

Agricultural plastics, particularly mulching films, are mostly made from polyethene (PE) or low-density polyethene (LDPE). Agriculture plastic products are used to improve water use efficiency, prevent weed growth, reduce soil erosion, and eventually improve crop yield. The plastic mulching film has been introduced in Cambodia for nearly a decade and has gained popularity among vegetable growers. Aside from plastic mulch, plastic bags are also often used in agriculture. Its convenience, accessibility, and affordability are the main driving factors of usage (Chitotombe and Gukureme, 2014; ACRA, 2015). As such, plastic bags were also considered in this study due to the frequency and intensity of its use in urban and rural settings.



From our report on the environmental impact of plastic products in horticulture activities, we found out that plastic mulch usage could amount to 235 kg/ha/year, and dripline is around 228 kg/ha/year, which signifies the potential market demand as well as its waste production. Thus, this report analyses the market opportunity of alternative plastics for horticulture practices. There are different kinds of plastic mulching films with various qualities and prices available in Cambodia. Some plastic mulching films can be used for at least two crop-growing cycles, whereas others can barely last a crop-growing cycle before breaking into small pieces, and it is nearly impossible for farmers to remove these pieces of plastic from the soil.

Recently, there has been increasing concern over macro and microscopic plastic residues in the soil, which threaten sustainable agriculture and food safety. Some companies are considering ways to produce compostable plastic or recycle plastic waste into reusable products. One example is renewable cassava starch mixed with biodegradable polymer cornstarch and various synthetic compounds, including natural plasticisers and hydrophilic substances biologically degradable from synthetic polymers, to create Mater-Bi. Mater-Bi is a biodegradable material used as an environmentally friendly alternative to polyethylene-based plastic products.

Some biodegradable and compostable products exist in Cambodia, but these products do not decompose quickly enough for agricultural purposes. Biodegradable products will degrade within five years, whereas compostable products can decompose fully in less than two years. Some products can fully decompose in less than four months after being buried in the soil. These products need to be imported and are currently too expensive for widespread adoption within the agricultural sector of Cambodia. At present, common commercially produced biodegradable bioplastics include Polylactic acid (PLA), PBAT, PBS, and Poly (hydroxyalkanoates) (PHA). PBAT, PLA, and their composites are the best-performance and economically viable biodegradable plastics available in



the market (Saraswat et al., 2022). Therefore, this market study aims to analyse the possibility of substituting conventional plastic products for Cambodia.

Biodegradable products will degrade within five years, whereas compostable products can decompose fully in less than two years.

Alternatives to Horticultural Plastics

Intensive use of plastic in Cambodian horticulture will produce a huge amount of solid waste generated during the production and service process. Based on our study on plastic products from horticulture practice, the potential horticultural plastic usage is approximately 515,450 tonnes/year throughout Cambodia. This amount represents a likely market demand and challenge in the disposal phase. In many regions, agricultural plastic waste disposal options are on-site burial, on-site burning, illegal dumping, and disposal in landfills (Rentizelas et al., 2018). Likewise, 95% of farmers in our study area burn their plastic waste. Since the waste collection services to landfills are still decentralised in Cambodia, especially in rural areas, the farmers often choose the first three disposal methods. Adopting these practices is also driven by the high waste transport and storage cost, which does not justify the farmer's commitment and investments.

Recycling is not always a viable option for better waste management practice, but its affordability depends on the type of plastic, the degree of contamination, and adequate sorting (G. Scarascia-Mugnozza et al., 2008). Agricultural plastic products are most often composed of homogeneous polymer types, which is favoured for mechanical recycling of agricultural post-consumer films. However, most of the used agricultural plastic is contaminated by dirt and pesticides, which means it requires additional treatment with laborious processes and high related costs. The recycling operations



and the low quality of the material to be recycled result in high costs that make this process uneconomical (Galati & Scalenghe, 2021). Therefore, finding an economically practical solution to manage agricultural plastic efficiently will be crucial for disentangling the plastic pollution issue (Borrelle et al., 2020).

Biodegradable plastic products could meet circular economy aims and principles if the supply of renewable materials is based on a sustainable approach and the conversion processes along the supply chain are efficient and highly integrated into the Life Cycle Assessment (LCA) (European Union, 2018). Plastic products claiming to be biodegradable must pass certain testing to prove their degradability and ecotoxicity. For instance, in the European market, the biodegradable mulch material specification is ratified by the European Standard EN 17033:2018 concerning “Plastics - Biodegradable mulch films for use in agriculture and horticulture - Requirements and test methods” (Razza et al., 2020). Another standard are ASTM D6400-21² and ISO 17088:2021³.

It provides the necessary tests and limits to define the biodegradability, performances, and environmental impacts of bio-based mulch films.

“The potential horticultural plastic usage is approximately 515,450 tonnes/year throughout Cambodia. This amount represents a likely market demand and challenge in the disposal phase.”

² ASTM D6400-21 is a specification that outlines compostable plastics and products designed for efficient composting in industrial facilities, ensuring they biodegrade at a rate comparable to established compostable materials.

³ ISO 17088:2021 sets out specifications for compostable plastics, including guidelines for their disintegration, aerobic biodegradation, effects on terrestrial organisms, and constituent control during industrial composting, serving as a foundation for labeling and claims on compostable plastics but not addressing litter biodegradability or small-scale household treatments.



The material is considered completely biodegradable if it achieves complete biodegradation in a test period of no longer than 24 months. It also provides standards for ecotoxicity testing through acute and chronic toxicity tests on plant growth and earthworm and nitrification inhibition tests with soil microorganisms. The certified alternative plastic guarantees that the product will completely biodegrade in the soil without adversely impacting the environment (Razza et al., 2020).

Trend of Plastic in Cambodia

In general, plastic usage in Cambodia is very high, which is in line with plastic production and consumption globally; based on Plastic Atlas (2019) study, more than half (56%) of all the plastics ever produced were made since 2000. Between 2014 and 2015, the global per capita consumption of plastic was 28 kg annually (UNEP, 2020). China is the largest single-use plastic producer, followed by the US and India. In this year, the amount of plastic mulch being shipped from other countries is 124,700 shipments⁴. As for plastic bags, the demand in 2020 has already reached 300 million tonnes per year (MIDA, 2020 in Moshood et al, 2022a).

As for Cambodia, a 2015 research study reported that about 10 million plastic bags were consumed daily in Phnom Penh. Moreover, on average, the urban Cambodian people use more than 2,000 plastic bags (per capita) each year, which is ten times higher than the European Union and China (Retka and Narim, 2016, Pech, 2017 in Koeng, 2020). Plastic usage can also be seen from the amount of plastic waste. It increased about three-fold from 6% in 1999 (MoE, 2004) to 17.8% in 2013 (Seng et al., 2013), 20.9% in 2015 (Hul et al., 2015), and 21.2% in 2016 (Bandith and Fujiwara, 2016 in Koeng, 2020). Based on Hul et al. (2015), the primary component of plastic waste is plastic bags, which account for 75.5% of the total plastic

⁴ <https://www.volza.com/p/plastic-mulch-films/import/import-in-cambodia/>

waste, with composition as follows: white plastic bags (51.9%), coloured plastic bags (23.6%), and other plastic bags (24.5%). As for the source, the plastic bag from the municipality comprised 15.8%, whereas the household plastic bag comprised 14.2% in 2015 (Hul et al., 2015). On the other hand, the non-household plastic bag composition was 13.5% in 2014 (Mongtoeun et al., 2014).

The rise of plastic demand in Cambodia is also depicted by the number of plastic imports to Cambodia. Since 2012, plastic products imported to Cambodia have risen sevenfold to US\$96,097,000 in 2021.

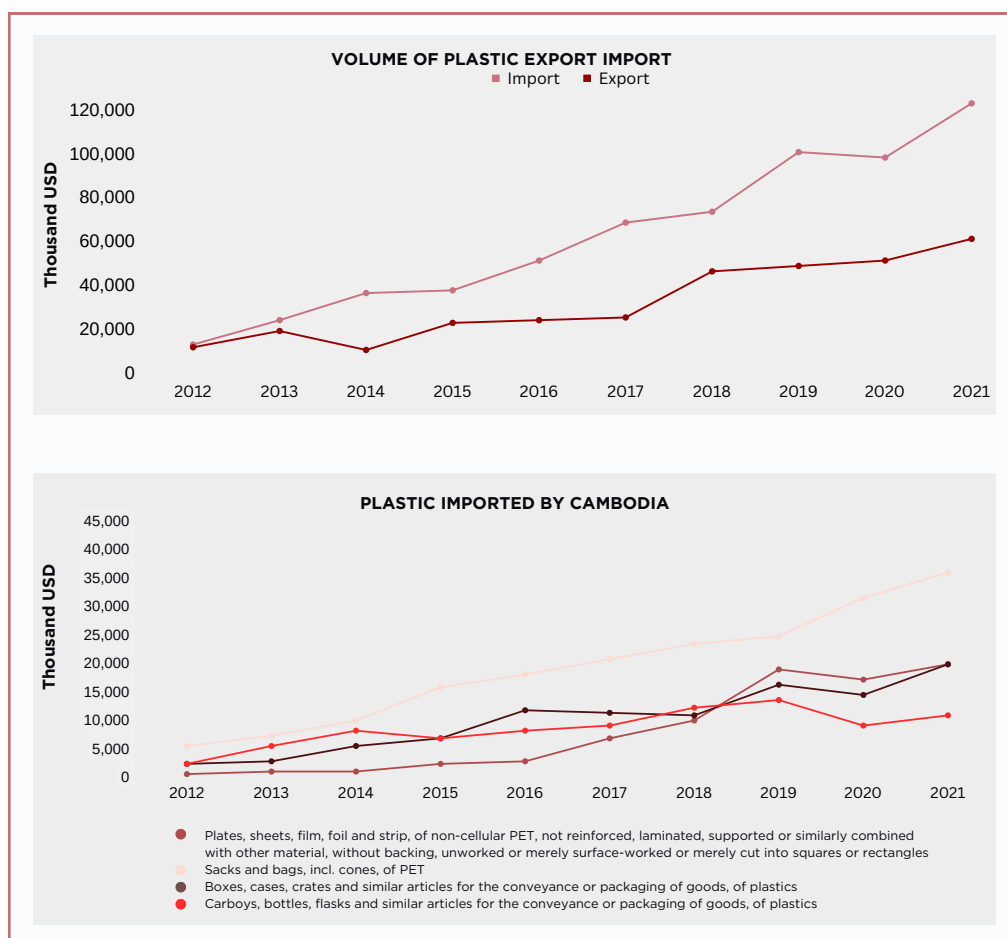
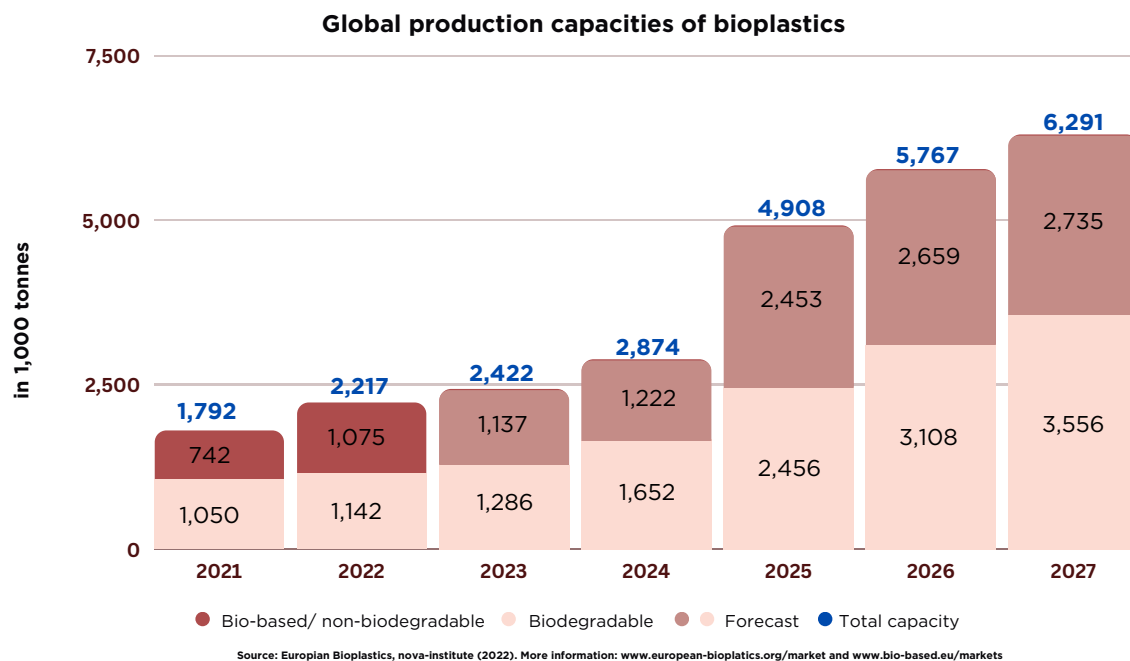


Figure 1. The volume of exports and imports in Cambodia (top) and imported plastic based on type of product (bottom)
(source: <https://intracen.org/>)

Since 2012, plastic products
import to Cambodia has risen
seven fold.

The rise in demand is particularly steep for sacks and bags made from PET (polymers of ethylene) (Figure 1). Likewise, sheets or films of PET (including plastic mulch) have increased significantly in the past years to US\$21,942,000 in 2021.



Global production capacities of bioplastics 2022 (by market segment)

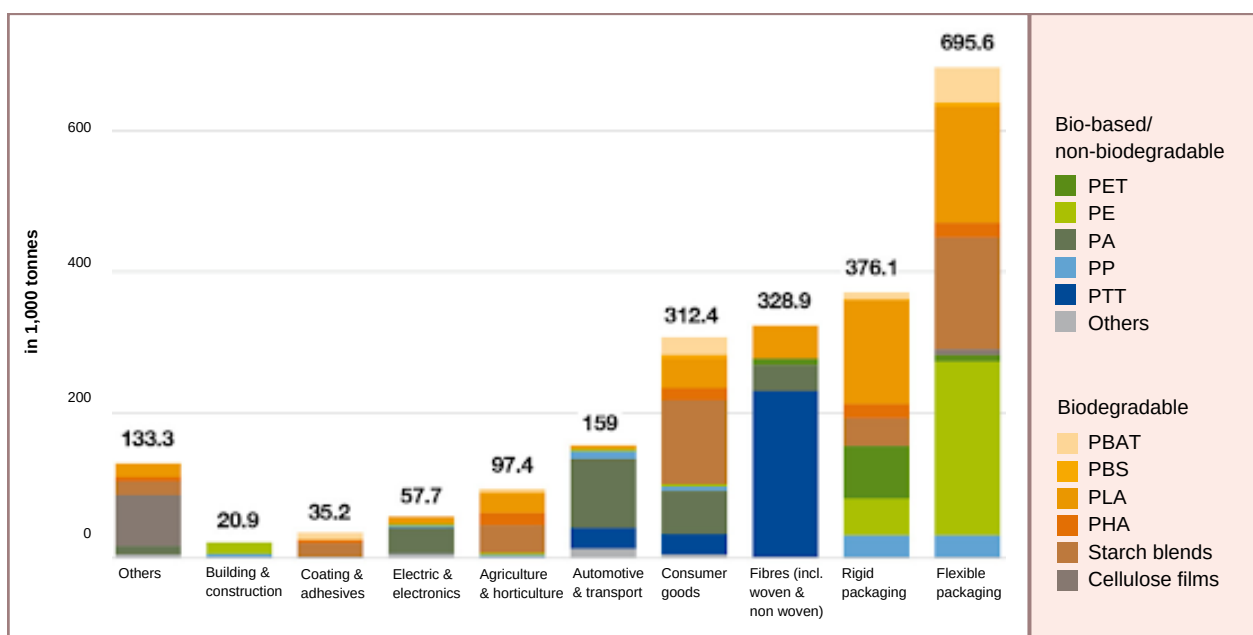


Figure 2 Global trend of biodegradable plastic
(source: <https://www.european-bioplastics.org/market/>)

The trend of biodegradable plastic is rising along with global awareness of plastic pollution (Figure 2). Although the portion of bioplastic in the agriculture sector globally is still low (97,400 tonnes in 2022), the usage of bioplastic has already risen in flexible packaging means that the industry of bioplastic and biodegradable is on the rise and will spread into the agriculture sector. It is predicted that by 2025, bioplastic can grow up to 30% annually (Moshood et al., 2022a). A Malaysian Investment Development Authority report predicted that the biodegradable plastics market was expected to rise from US\$3.02 billion in 2018 to US\$6.12 billion by 2023 at a compound annual growth rate of 15.1 per cent (Malaysian Investment Deve-



lopment Authority, 2020). The report based the calculation on the growing demand in developing economies such as Malaysia, India, China, and Brazil in various end-use industries (Moshood et al., 2022a). Another report even predicted a higher share of US\$20.9 billion by 2028, at a compounded annual growth rate (CAGR) of 21.3%, in which Asia Pacific region holds the majority of the share of 20% (Markets and Markets, 2021). A rising trend was also observed in Cambodia, where bioplastic and recycled products enterprises are emerging and environment-friendly products are gaining popularity with the public (Seavmey, 2023).

The Ever-growing Market of Horticultural Plastic in Cambodia

The total global production of bio-based and biodegradable plastics in 2019 was 2.1 million tonnes per annum, with production growth of 14% over four years. If plastic production stays constant in the next ten years, biodegradable plastics will rise to about 2% of the total plastic market. By 2024, the global market for bioplastics and biopolymers is projected to reach US\$14.9 billion by 2024, registering a CAGR of 15.6% over the analysis period (Saraswat et al., 2022).

The estimation of the total available market (TAM) of plastic mulch in Cambodia is estimated from the total area of crops that might be in need of plastic mulch. We define this using the categorisation provided by CAS 2020: vegetables and melons, legumes, spices and aromatics, and fruits and nuts, with a total area of 824,725 ha. Since not all crops use plastic mulch, we set the assumption to 1.5% of the total agricultural land area,⁵ hence the total estimated area became 206,000 ha. Using this area, the average prices of buying plastic mulch per roll, and the average margin the seller puts for plastic mulch, we can calculate the TAM. As for the serviceable available market (SAM), we define this based on the assumption that our survey represents the average ratio of plastic mulch users,

⁵ The worldwide comparison of plastic mulch usage to total agriculture land in 1999 is 1%. In China the number is 3% in 2002. In this study 1.5% is used considering Cambodia is still in early stage of adoption.

which is 67% of the farmers. Lastly, for the obtainable ratio for an alternative to current plastic mulch, we set an estimation of 10%, considering the number of farmer respondents that showed interest in using biodegradable plastic. From these assumptions, we found the TAM, SAM, and SOM for plastic mulch alternatives in Figure 3. From the estimation, it is seen that plastic nets and containers also have a large available market due to their large volume of usage in the agricultural sector.

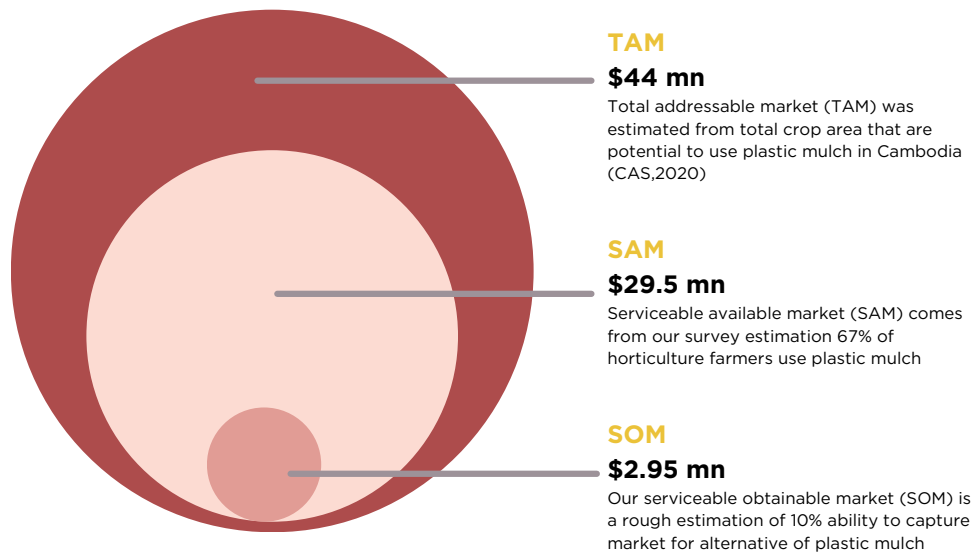


Figure 3. TAM, SAM, SOM, of plastic mulch alternative

Aside from plastic mulch, we also estimated the TAM, SAM, and SOM for other plastic products surveyed in our study, as displayed in Table 1. The value of plastic bags is estimated from the annual use of plastic bags in urban settings and the urban population of Cambodia. The SAM calculated for plastic bags is 10% of the TAM; 10% is the projection of how big the supermarkets and hypermarkets will take share in the overall retail market in Cambodia . The SOM of plastic bags is derived from 90% of the SAM, where 90% is the number of respondents in this study who are willing to use biodegradable plastic. The market for biodegradable plastic bags in urban areas could be bigger than the number depicted in Table 1 as we are not accounting for the biodegradable plastic demand for other plastic products used for takeaway commodities (i.e., single-use straws, spoons, forks).

6 Currently, the traditional open markets have been the standard shopping channel for many Cambodian consumers (<https://www.fitchsolutions.com/food-drink/grocery-retail-spending-grow-steadily-cambodia-although-focus-remains-essentials-23-08-2022>). A survey conducted in 2009 (n = 600) found that traditional markets were the most often used retail format for shopping, followed by local shops and street vendors (Indochina Research, 2009 in <https://phnompenhpost.com/business/most-cambodians-still-shop-markets-survey-discovers>). According to Euromonitor, supermarkets are still a relatively small channel in Cambodia, accounting for only 2% of total retail sales in 2021 (<https://www.euromonitor.com/retailing-in-cambodia/report>)

PRODUCT	TAM	SAM	SOM
Plastic Mulch	US\$44,000,000	US\$29,500,000	US\$2,950,000
Plastic net	US\$29,800,000	US\$13,400,000	US\$1,340,000
Plastic container	US\$18,500,000	US\$9,260,000	US\$926,000
Dripline	US\$1,100,000	US\$850,000	US\$85,000
Water hose	US\$955,000	US\$550,000	US\$55,000
Plastic packaging	US\$790,000	US\$750,000	US\$75,000
Plastic bags (urban)	US\$126,000	US\$6,300	US\$600
Total	US\$95,271,000	US\$54,316,300	US\$5,431,600

Table 1. Overall TAM, SAM, SOM, of plastic products alternative

Market's demography and perception

The interviews showed that while most surveyed farmers own the land (or in an owner-like scenario), the average area for rented areas is bigger. However, the gross profit margin (GPM) for a renting farmer is lower than the landowner, which is 47.7% compared to 60.9%. The lowest annual revenue is US\$125, while the highest is US\$25,000, with an average of US\$373. Renting farmers have a lower average than farmers who own the rent, with an annual revenue average of US\$313 and US\$389, respectively⁷.

Market description of plastic products in Cambodia

There are two primary market functions for bioplastics in general: to enable ease of organic plastic management in urban settings and to alleviate plastic pollution in the environment. Bioplastic bags are designed for the first purpose, whereas agriculture bioplastic is designed for the latter. As for the trend of the market, just like other products, the development of biodegradable plastic is very consumer-driven, meaning that awareness of the market plays a big role in determining the success of bioplastic products. On the other hand, the awareness can be improved significantly with the evidence of micro and macro plastics' existence in the food system, which will likely take place in five years.

⁷ This number is below the reported average annual profit from CSmart farmers, who reported annual profit from US\$830-1,040. As such this study showed a perception from farmers from a wide range of income, thus we divide the respondents into four categories of income

The estimation of plastic bag usage in Cambodia is around 2000 pcs/year in urban settings (Koeng et al., 2020). Most of the plastic bags were obtained from wet markets (a source of 50% of household plastics). The plastic bag in the wet market is used extensively to wrap each commodity bought to make it clean and deemed good customer service. Some stalls go through two to three kilos daily, which corresponds to about \$20/week (17Triggers, 2015).

In principle, the cost of using and disposing of conventional plastic bags is not necessarily cheaper than a biodegradable bag (New Strait Times, 2019). A report by BlueWeave Consulting on the Vietnam biodegradable plastics market stated that the price between conventional plastic and biobased one does not differ much; they found that conventional PET resin costs US\$2.1 per kilogram while Bio-PET resin costs US\$2.3 per kilogram. Nonetheless, the production cost could be higher by 20–80% on top of the material cost (Markets and Markets, 2021).



The development of biodegradable plastic is very consumer-driven, meaning that awareness of the market plays a big role in determining the success of bioplastic products.



Interviews suggest that there are mainly two kinds of plastic mulch used by farmers in Cambodia, both of which have PE material but with different thicknesses and quality. The farmers refer to these as the Thai variety and the Vietnam variety, with the Thai variety having better durability due to thicker material. On average, the Thai variety is priced at around \$27.53 per roll, while the Vietnam variety is \$12.5. In a more detailed manner, the retailer sold Vietnam-type mulch for around \$15 per roll, while the Thai type cost \$30. On the other hand, the wholesaler sold the Vietnam type for \$12.45 per roll and the Thai type for around \$29.38. The income from selling plastic mulch varies throughout the year due to seasonal usage of mulch, but on average, the retailer earns \$566.81/month while the wholesaler earns \$1,139.55/month. Most interviewed retailers and distributors agree that plastic mulch usage has increased over the past five years and believe it will continue to do so in the future due to more farmers being exposed to mulching practices.



Plastic supplier

The plastic supplier interviewed for this study comprises manufacturers (n = 4), wholesalers (n = 5), and retailers (n = 6). The manufacturers were producers of bioplastic, which is an alternative to single-use plastic and plastic packaging, such as Biobag World Australia, Cassaplast from Indonesia, and HRK Group from Vietnam.

Generally, there are three types of bioplastics: biopolymer-based plastic, biodegradable and compostable plastic. Bioplastic products are declared to be a solution for countries with limited waste management options, particularly for those with limited landfill capacity or countries with low rates of plastic recycling, reuse, or reduction activities. The current development is compostable plastic that can be thoroughly degraded and give additional nutrition to the soil. The most advanced bioplastic is the one that can be ultimately soluble in water. Although it is still in development in China, Japan, and Europe, the product has great potential to reduce marine pollution.

Currently, there are few manufacturers⁸ of biodegradable plastic products in Cambodia, one of which is Cleanbodia. This company produces biodegradable and compostable plastic bag alternatives that are manufactured from a combination of cassava starch and fossil fuel. The rise of small bioplastic enterprises in Cambodia signifies the demand for a more environmentally friendly product in the community. As such, a number of conventional plastic manufacturers in Cambodia⁹ should consider entering the biodegradable plastic earlier to have a headstart from the neighbouring countries.

⁸ Most of the manufacturers in Cambodia are small or social enterprises that focus on producing bioplastics such as drinking straws from rice flour with fruit powders and using banana trunks to make environmentally friendly bowls (<https://cambodianess.com/article/bioplastics-step-up-for-a-cleaner-environment>)

⁹ The plastic manufacturers in Cambodia produce various types, including plastic bags, packaging, and other plastic products. They are Modern Plastic And Packaging Cambodia, Juyuan (Cambodia) Co., Ltd., Huakang Packaging Technology Co. Lt, Taperite Plastic Co., Ltd., Sao Yu Pheng Packaging And Plastic, Aap Group, Mtc Master Taste (Cambodia) Co., Ltd., Phnom Penh Plastic, Visca Plastics Jsc.



There are also some manufacturers of biodegradable plastic located in neighbouring countries. The notable biodegradable plastic manufacturers are located in Thailand, which is now the second-largest producer of bioplastics in the world behind the U.S. This was contributed to the Thai government's commitment to the bio-circular-green (BCG) economy¹⁰. Other manufacturers are DRN Manufacturing Sdn Bhd in Malaysia, BioPak in Singapore, CJ Cheiljedang in Indonesia and Nlytech Biotech in Malaysia. This is in line with a study by European Bioplastic (2022), which pointed out that Asia countries have a great potential to supply the material for bioplastic, as they are based on agrarian economy, which implies the abundance of agricultural residues to be used for biodegradable plastics. The study stated that Asia will increase biodegradable plastic production to almost 63 per cent by 2027 (European Bioplastic, 2022).

The current development is compostable plastic that can be thoroughly degraded and give additional nutrition to the soil. The most advanced bioplastic is the one that can be ultimately soluble in water.

The rise of biodegradable plastic manufacturers is in line with the demand from many brands in Southeast Asia that are determined to produce eco-friendly products. For some products, manufacturers have obtained certification from countries like Austria and Australia. The certification itself is essential when purchasing a compostable plastic product, as it shows that the product will be degraded completely in the environment.

The manufacturers can also customise the bioplastic needed from the product to serve the duration of the crop cycle.

¹⁰ <https://thaiembdc.org/2023/03/09/thailand-is-now-worlds-second-largest-maker-of-bioplastics/>



The ability of the manufacturers to produce varied bioplastics becomes the key to the sustainability of their business model because the market demand could fluctuate based on the development of environmental laws and regulations. For instance, one manufacturer could provide raw materials, pellets, semi-finished products, and finished products that can meet the needs of different sectors (i.e., farmers, retail, and other manufacturers).

On the other hand, almost all of the distributors of plastic products (wholesalers and retailers) that we interviewed (n=7, 63%) saw an increasing trend of agricultural plastic usage. Most of them (n=9, 82%) confirmed that they are willing to sell biodegradable plastics if the price is still affordable; they are even already aware that conventional plastic harms the environment, particularly the detrimental effect plastic has on the soil.

The same sentiments were shared by a supermarket in Phnom Penh that stated that the trend for biobag usage is growing in Cambodia. The supermarket has been selling bio-garbage bags for \$2.2-5.9/kg and handle bags for \$2-4.5/kg. Nonetheless, there are objections regarding the price: there is hesitancy shown from the local factory and company and some customers who object to the higher cost of a biobag. However, this challenge can be tackled with financial incentives or cross-subsidies from charging the usage of conventional plastic bags. Charging of conventional plastic bags has been imposed since 2017, where supermarkets and shopping malls imposed KHR 400/bag (~US\$0.10/ bag) and reduced the distribution of plastic bags by 30% (Chakray, 2020). As such, there should be a general fee for plastic bags imposed by the government, along with the urge for vendors to stop providing free plastic bags to consumers on a voluntary basis (Vara, 2019) so that the biobag policy implementation could take place.



The motion towards environmentally friendly products was also pushed by the government. Currently, Cambodia is revising sub-decree 168, which regulates single-use plastic bags, to include more plastic products, including agricultural plastic. In Cambodia, there are also many NGOs that are concerned with the impact of plastic, although iDE is the first to highlight the impact of plastic on agriculture. The drive from the government was evident in Costa Rica, which is planning to replace 80% of the country's disposable plastic packaging with non-petroleum renewable materials that can biodegrade within six months, even in a marine environment (Saraswat et al., 2022).

“Almost all of the distributors of plastic products (wholesalers and retailers) are willing to sell biodegradable plastics as long as the price is still affordable.”

Plastic recycling and upcycling

Another growing market is plastic upcycling across Asia and Africa. Previously, the demand for plastic recycling was growing in Cambodia; however, since there is a ban from China to receive recycled plastic, the business has declined significantly. On the other hand, plastic upcycling can convert low-quality plastic into marketable products such as plastic boards, sheets, and furniture. The type of business can range from social enterprises, individuals, or industries. An example of a social-based enterprise is in the Philippines and Vietnam, where the plastic upcycling business established value chains with informal sectors, waste banks, and other stakeholders of plastic waste collection to collect plastic waste. This is done by building infrastructure like collection points, providing training to the local communities to start doing some waste segregation and separation and working on the capacity for the local junk shops to have better environmental compliance



These efforts enable the company to collect favourable and adequate plastic waste to be upcycled and marketed. Apart from developing the value chain, the company also sells a low-cost upcycle machine that any waste operator, municipal sites, private, and entrepreneur can use. The low-cost components enable the product to be competitive, if not priced similarly, to plywood boards in Vietnam. Another option to make the business feasible is to work with existing plastic industries and have the upcycling system as an add-on; this way, the business will save the operational cost for procuring some of the machinery and permit for managing plastic as well as ensuring the supply and quality of plastic waste needed to be upcycled.

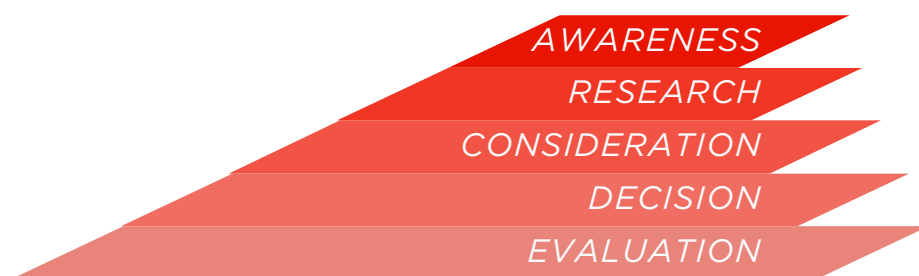


The low-cost components enable the product to be competitive if not having the same price as plywood boards.



Market profiling

In this research, we describe the profile of the market of plastic mulch in Cambodia through its customer journey experience. The stages are awareness, where the farmers are introduced to plastic mulch; consideration, explaining aspects considered by the farmers to use or not use plastic mulch; decision, the overall experience with plastic mulch; and evaluation, the likeliness of repeating the use of plastic mulch and desired improvement for the product. Later, through several parameters, we also cluster and segment the surveyed farmers into several parts.



a. Awareness

High awareness and openness to new practices

We found that almost 98% of surveyed farmers know about plastic mulch. From Figure 4, the top three ways farmers are exposed to plastic mulch practice is through introductory programs from governments and development partners (31.7%), fellow farmers' recommendation (23.2%), and consumer recommendation (20.7%). All in all, it can be insinuated that most farmers are passive in looking for new practices to be implemented in their field and only do so when there is reputable advocacy from other parties such as the government, the private sector, NGOs, sellers, and fellow farmers.

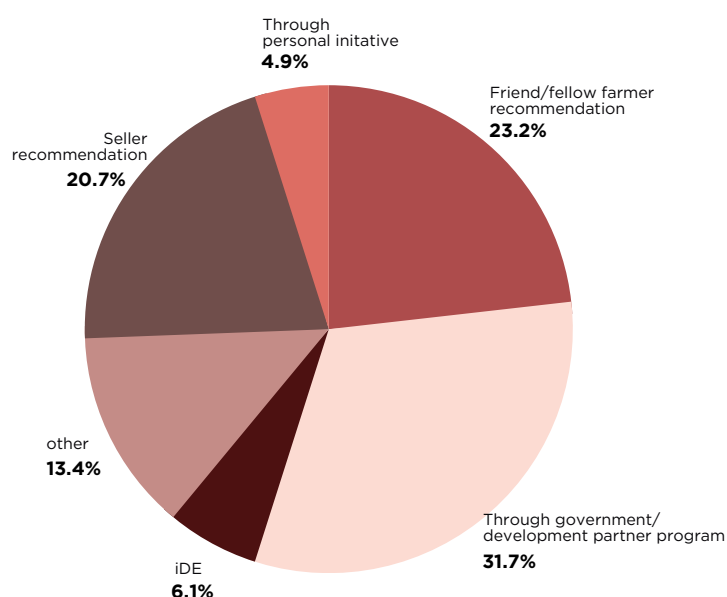


Figure 4. Consumers' information source regarding plastic mulching

Likewise, the people in Phnom Penh City are also aware of the existence of biodegradable plastic or bio-plastic. Out of 114 respondents¹¹ that we surveyed in Phnom Penh city, 73% were aware of the existence of bioplastic products. Most of them (90%) stated their preference for using biodegradable plastic in contrast to using conventional plastic.

Farmers' environmental perception and waste management practice

From our study, we found that farmers tend to agree with the statement that plastic waste is bad for the environment. As many as 56% of farmers also stated to be willing to start recycling their plastic, given sufficient infrastructure available. Figure 5 shows farmers' environmental perception.

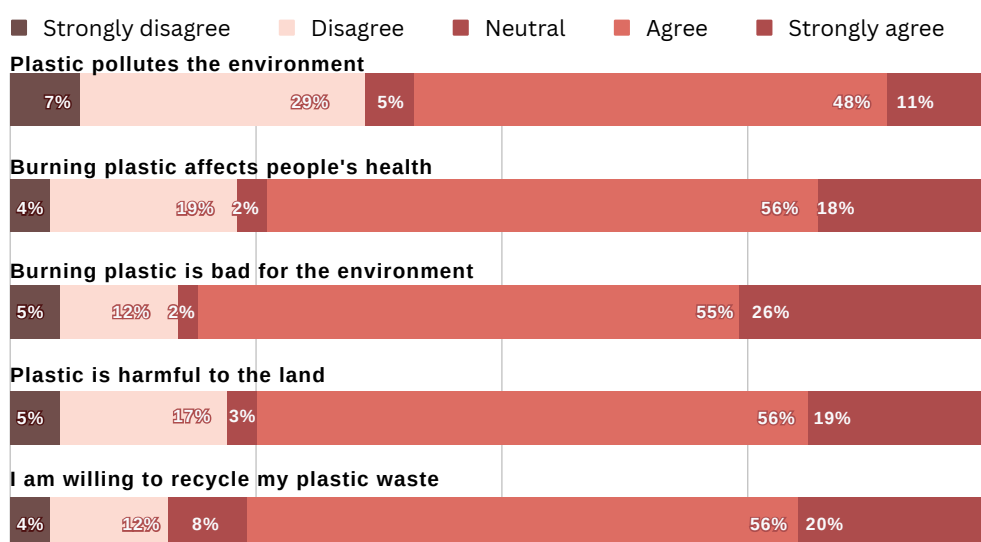


Figure 5. Environmental perception of Cambodian farmers

In using plastic mulch, farmers usually remove the plastic at the end of the plastic use. The removal process can be labour-intensive, expensive, and incomplete. Currently, farmers cannot fully collect their plastic mulch, partly because the ones they use are mostly torn and embedded in the field after a planting season, and recollecting them will take too much time and effort. As such, some farmers would only gather all the collectable parts of plastic mulch and leave the remaining in the field. The collected parts would mostly be burned (95%) or buried, only a small percentage of respondents piled it or let it be collected by a third party (1.7%).

¹¹

The respondents were comprised of 60% male and 40% female, age from 17-45 years old, with most of them (41%) between 29-32 years old.



Farmers tend to agree with the statement that plastic waste is bad for the environment.



However, 80% of the farmers want to change their current waste management practice, indicating that this is an ongoing issue for which they want a solution. Substitution for biodegradable plastic mulch can use this factor as an entry point for the product, becoming a less wasteful solution for farmers who want to continue using plastic mulch.

b. Consideration

Soil and water is the key to a good harvest

There are many factors that farmers consider in doing their practice. In our survey, we found that farmers think the priority in increasing their crop productivity is the quality of soil and water, crop varietal, and fertiliser usage, as shown in Figure 6. These factors contribute to the decision to use plastic mulch by farmers; for example, plastic mulch can support water management in the farmland by retaining water during the dry season and repelling water during the rainy season, as well as soil management by reducing weed occurrence.

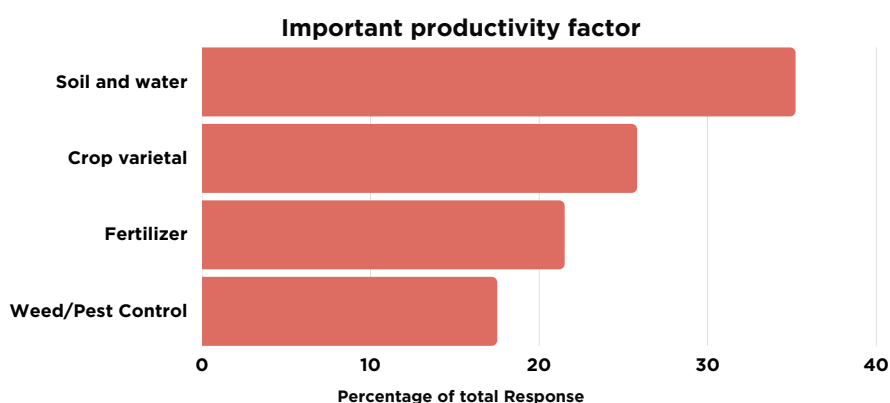


Figure 6. Ranking of crop productivity factors importance perceived by surveyed farmers

However, we also found that only 67% of surveyed farmers used plastic mulch, which indicates a higher priority in other factors in considering whether to use plastic mulch. From the survey, the highest reason farmers do not use plastic mulch,

even when they are aware of its benefits, is the higher cost due to the purchase of plastic mulch. Figure 7 shows the full recap of why farmers do not use plastic mulch.

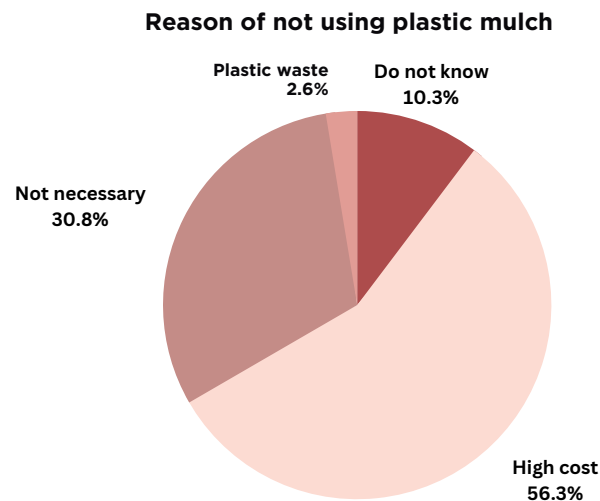


Figure 7. The reason of farmers not using plastic mulch

The calculation of the average annual operation cost somewhat supports this. We found that plastic mulch usage contributes around 14% on average to the annual operation cost. While it seems small, farmers may perceive the higher upfront cost in purchasing plastic mulch at the start of planting season can be the biggest obstacle to them using it. A similar finding was also reported for plastic bags in urban settings. ACRA reported that if the price of an alternative material is low enough, the material would be accepted by more customers (ACRA, 2015 in Koeng, 2020).

c. Decision

Experience in using plastic mulch

In general, farmers who use plastic mulch have a positive perception of their experience in using the product, with the quantified result of 76% positive feedback. Figure 8 lists all the perceptions that users have regarding plastic mulch.

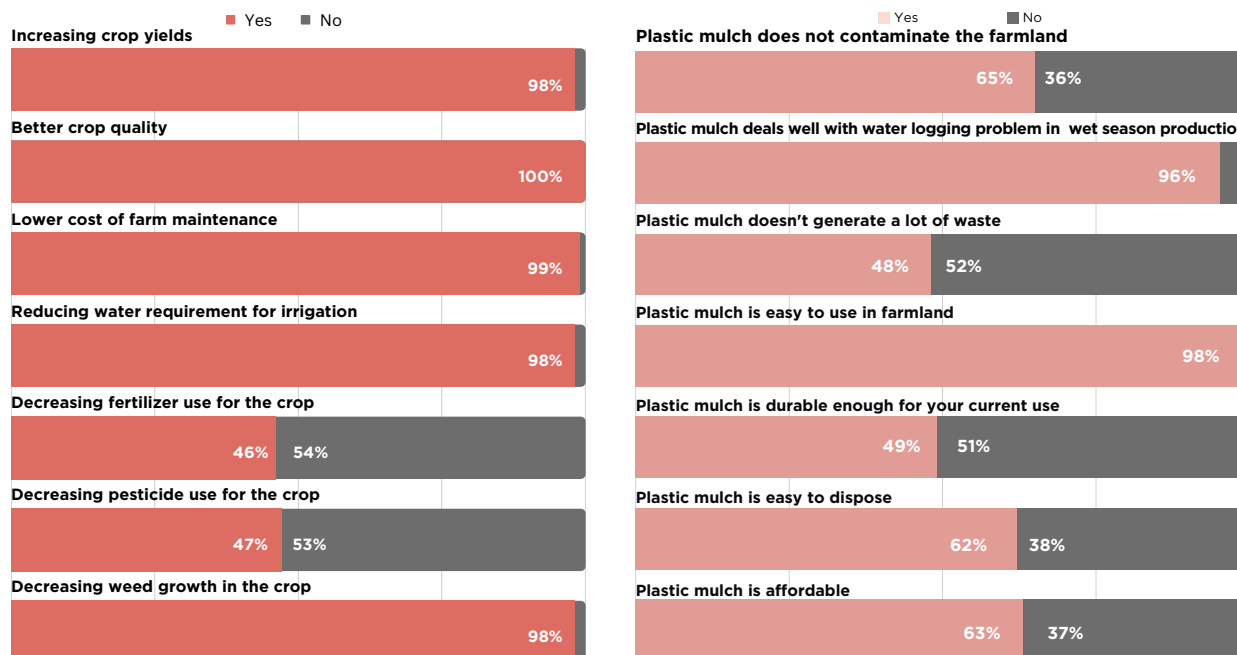


Figure 8. Farmer's perception of plastic mulch

The perception about plastic mulch that most farmers agree with is that plastic mulch increases crop yield and quality, lowers maintenance costs for weeding, and reduces water usage and weed problems. However, more than half of the farmers also agree that the plastic mulch that they use generates a lot of waste and is not durable enough to their liking. From the purchasing experience, there seems to be no problem accessing plastic mulch. Farmers can buy from retailers and wholesalers at the city, district, and community levels.

d. Evaluation

Likely to continue using plastic mulch

Of the surveyed farmers who use plastic mulch, 99% are willing to continue using the product in the foreseeable future. However, there are several improvements that the user wants regarding the product, which are increasing its durability and affordability and decreasing its impact on the land. Figure 9 recaps all the desired improvements by the farmers.

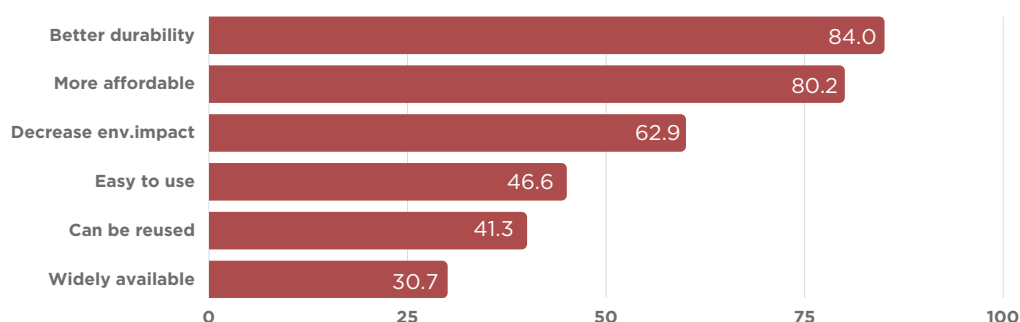


Figure 9. Desired improvement of plastic mulch

Potential customer classification

We divided our surveyed farmers into four categories according to CAS, as seen in Table 2.

Table 2. Categorisation of farmers' annual revenue

Revenue	Category
> US\$1950	1
US\$730 - 1950	2
US\$243 - 730	3
US\$0- 243	4

From this, we found that nearly 50% of our surveyed farmers have a revenue of more than US\$1,948 per year. The breakdown of the farmers' annual revenue can be seen in Table 3.

Table 3. Categorisation of farmers' annual revenue

Revenue Category	Percentage of Farmers
1	46.22%
2	31.09%
3	18.49%
4	4.20%

We also surveyed their willingness to pay (WTP) between conventional and biodegradable plastic mulch. Thus, the differences between those two parameters in each category can be observed. Figure 10 shows the breakdown in each category.

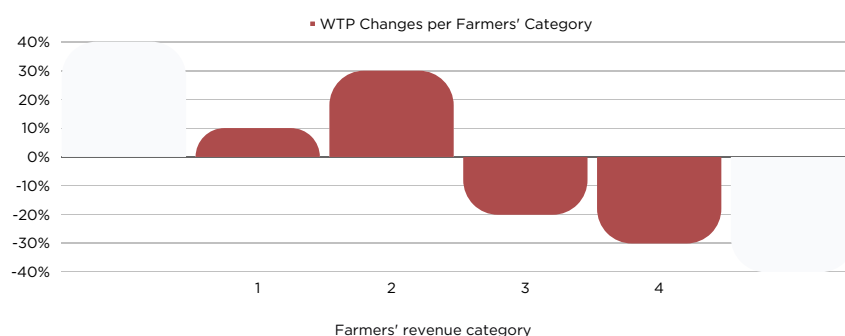


Figure 10. Trends of WTP changes in farmers

Farmers in categories 1 and 2 are willing to pay higher prices for biodegradable plastic mulch, with an increase of 10% and 30%, and even higher WTP for conventional plastic mulch. This is because conventional plastic mulch is more durable than the biodegradable one. The farmers in category 2, who have lower revenue than farmers in category 1, have higher WTP for the plastic mulch because they know that they have not reached the maximum profit that can be obtained. This is corroborated by a significant correlation observed between WTP for conventional plastic mulch with operational budget ($p = 0.4$) and revenue ($p = 0.289$). There are also some common characteristics of farmers with higher WTP, such as having more than one type of plant (which mostly includes different types of melon, such as rice melon, sweet melon, bitter melon, and watermelon). As for the WTP for biodegradable plastic mulch, the only significant correlation was observed in farmers who perceive that plastic pollutes the environment ($p = 0.219$). The market for biodegradable plastic is still in a niche stage; 97–99% of all the plastics in the world are still derived from fossil fuel feedstock, while only the remaining 1–3% come from bio (plant) based plastics (UNEP, 2020).

As for bioplastic bags in urban settings, most of the respondents ($n = 91$, 80%) were willing to pay US\$0.1 for a biodegradable plastic bag. A similar trend was also observed for the WTP of bio-garbage bags¹²; most of the respondents were willing to purchase the product for US\$2.2/kg, although the percentage ($n = 83$, 73%) is lower than the bioplastic bag. The same result ($n = 83$, 73%) was observed for handle bags¹³, which has the same price range (US\$2–4.5/kg). These trends show a positive projection of the acceptance of biodegradable plastic products in Cambodia, particularly in urban settings.



Farmers are willing to pay higher prices for biodegradable plastic mulch, with an increase of 10% and 30%.



¹² A bio-garbage bag is a 25 litre-sized plastic bag used to collect trash.

¹³ A handle bag is a durable bag made from cotton, nylon, polypropylene, or canvas.

Driving factors of pushing biodegradable plastic

Moving forward, Cambodia has the technology and material to have its own biodegradable plastic manufacturers, particularly for bio bags. Cambodia has an abundance of bio-bag materials such as cassava, corn and potato starch. The rise of small enterprises in bioplastics signifies the demand for more environmentally friendly products in the community. As such, a number of conventional plastic manufacturers in Cambodia should consider entering the biodegradable plastic earlier to have a headstart from the neighbouring countries.

However, for horticulture plastic products (i.e., plastic mulch, dripline, net), more rigorous research and development needs to be done to produce a material that can meet all the demands (durability, affordability but can be readily degraded in the environment). As such, to meet the demand for horticulture biodegradable plastic products in the short term, the government of Cambodia should provide incentives for overseas manufacturers who supply the product or for local manufacturers that venture into the biodegradable market. Other considerations that need to be taken are:

- ***Competitiveness of biodegradable plastic in comparison to conventional plastic***

Price is one of the main challenges for biodegradable plastic production because of the complex engineering processes and the research and development costs in order to produce the desired characteristic according to the consumer (i.e. durability of plastic mulch); however, less requirement is needed for developing bio bag.

Particularly for plastic mulch, as a relatively novel product, farmers will have various expectations of the biodegradable version, be it from its durability, degradability, and flexibility. Biodegradable plastic mulch may not perform as well as conventional plastic mulch in terms of weed control, moisture retention, and soil warming. This can affect crop yields and quality. Aligning expectations and educating customers will be significant in introducing biodegradable plastic mulch.

- ***Supportive market condition and no existing competitor***

The retailer, wholesaler, and distributor stated the increasing trend of conventional plastic products in the horticulture sector. Given the farmers' environmental perception and awareness of proper waste management practices and the impact of plastic pollution, a competitive and durable biodegradable plastic product will likely be in demand in the future market. However, no biodegradable plastic product for horticulture activities is available in the market. A study by European Bioplastic (2022) pointed out that Asian countries have a great potential to supply the material for bioplastic, as they are based on an agrarian economy, which implies the abundance of agricultural residues to be used for biodegradable plastics. The study stated that Asia will increase biodegradable plastic production to almost 63 per cent by 2027 (European Bioplastic, 2022).

For compostable and biodegradable bags, the trend is more promising since most urban respondents stated their willingness to pay for bio-bag products even if it is more expensive than conventional bags. Moreover, there is no specific requirement for the durability of the bio-bag compared to plastic mulch, which should be durable for at least three months under extreme weather conditions.

- ***Potential momentum from the government and other NGOs***

With the 2018 legislation on the pricing of single-use plastic bags from the Ministry of Environment, Cambodia has achieved significant improvements in environmental restoration. In addition, local start-ups are developing technologies to produce biodegradable plastic substitutes. Despite the fact that these technologies still need improvement for commercial viability and sustainability, the trends are encouraging.

- ***Further reduction in labour costs***

With the characteristic of biodegradable plastic, another value proposition that can be used as a driving factor to implement the substitution is reducing labour costs in terms of recollecting the used plastic mulch after planting season. Farmers usually remove the plastic at the end of the plastic use. The removal process can be labour-intensive, expensive, and incomplete. Currently, farmers cannot fully collect their plastic mulch, partly because the ones they use are mostly torn and therefore embedded in the field after a planting season, and recollecting them will take too much time and effort. As such, some of the farmers would only gather all the collectable parts of plastic mulch and leave the remaining in the field. The

collected parts would mostly be burned or buried; only a small percentage of respondents piled it or let it be collected by a third party (1.7%). As such, providing degradable plastic mulch could be an option for farmers, particularly for organic farmers who are obliged to remove 100% of plastic mulch.

However, the transition from conventional to biodegradable plastic may face challenges such as economic reasons, mismatched customer expectations, and low product knowledge, as well as low willingness to pay for alternatives to plastic mulch. These challenges could be a barrier to biodegradable plastic development in the market.

- ***Economic reason***

As seen from the consideration that farmers have in using or not using plastic mulch, one of the biggest contributing factors is the fact that plastic mulch adds to the cost of operation. According to our surveys, this will be exacerbated by the fact that biodegradable plastic mulch is at least almost two times more expensive than conventional one.

- ***Mismatched customer expectations and low product knowledge***

As a relatively novel product, future consumers will have various expectations of this product, be it from its durability, degradability, and flexibility.

Biodegradable plastic mulch may not perform as well as conventional plastic mulch in terms of weed control, moisture retention, and soil warming. This can affect crop yields and quality. Aligning expectations and educating customers will be significant in introducing biodegradable plastic mulch.

- ***Lower willingness to pay for alternatives to plastic mulch***

Currently, in our survey, the average WTP for biodegradable plastic mulch is lower than conventional plastic mulch, which is US\$16.93 compared to US\$19.13. This is caused by farmers who are aware that conventional plastic mulch is more durable than biodegradable ones. While this is not an all-encompassing average, the customers mainly want a more economical alternative to their current product. However, if we look at some customer segmentation, some customers are willing to pay more than conventional plastic mulch. At best, the biodegradable plastic mulch will have a niche segment of customers who are willing to pay more and are aware of the environmental benefits of biodegradable plastic.

Given the increasing demand for biodegradable plastics as a substitute for conventional plastics, the supply of biodegradable plastics presents a notable opportunity that is expected to extend to the horticulture sector. As highlighted

earlier, the current market for biodegradable plastics is relatively niche but is anticipated to expand gradually. International companies, especially those committed to eco-friendly initiatives, are expected to show interest in this emerging market. Furthermore, the Cambodian government should consider offering incentives to overseas manufacturers providing these products or local manufacturers entering the biodegradable market in the horticulture sector.

Conclusions and Recommendations

Conclusion of the study

In Cambodia, the need to substitute conventional plastic products that are used in the horticulture sector, particularly plastic mulch, is evident from the substantial concentration of microplastic found in the farming soil. An alternative to substitute conventional plastic products is biodegradable plastic, which can be disintegrated by the soil bacteria and prevent plastic build-up in the soil. Considering the importance of biodegradable plastic in ensuring sustainable horticulture practice, this study aims to provide an understanding of the biodegradable plastic market in Cambodia, particularly for horticulture activities. The information provided in this market is aimed at supporting the private sector and the government to support and be involved in the biodegradable plastic market.

The trend of biodegradable plastic is rising and is projected to take a bigger part in the coming years. The demand was created along with the global awareness of plastic pollution, as more microplastic was reported to be found in many parts of the ecosystem, including agricultural farmland. This is particularly true for bio-bags; a positive response and willingness to pay was observed through sampling (n = 100) in the Phnom Penh urban community. In addition, there is also a rise of small and medium enterprises in Cambodia that provide biodegradable plastic products for everyday use (e.g., cutlery, bags).

As for the horticulture sector, the total available market for plastic products is US\$95 million, the serviceable market is US\$54 million, and the serviceable obtainable market is US\$5 million. The number was mainly composed of plastic mulch, plastic nets, and plastic containers as the most used products in the horticulture sector. Although the SOM number is small compared to conventional plastic products, biodegradable plastic will be used to substitute plastic products. In addition, the projection of the biodegradable market is positive, as also reported in various market reports of biodegradable plastic products.

In the Cambodian horticulture sector, the main plastic products that are in demand are plastic mulch, plastic nets and plastic containers. According to retailers and



distributors, there has been a significant popularity rise in conventional plastic mulch among farmers. From the farmers' viewpoint, plastic mulch offers water and soil management benefits on the farmland. Although farmers are aware of the environmental impacts of conventional plastic, their average willingness to pay for biodegradable plastic mulch is US\$16.93, compared to US\$19.13 for conventional plastic. This is because conventional plastic is perceived as more durable. However, some customer segments are willing to pay more for the environmental benefits.

As for the the retailers and distributors, they were willing to sell biodegradable plastics if the price was still affordable. Unfortunately, the manufacturers of biodegradable plastic for horticulture products are not available in Cambodia; the nearest one is in Vietnam and Thailand. Overall, biodegradable mulch is likely to attract a niche market that values environmental advantages and farmers that are open to adopting new practices that offer benefits.

Recommendation for applying biodegradable plastic

Although well known, biodegradable plastic is still relatively new in the agricultural sector. From the driving factors and challenges, we developed several courses of action that are recommended to take to further advance the introduction of biodegradable plastic in the agricultural sector.

- ***Building environmental awareness in the government and in public***

Substitution of conventional plastic with biodegradable one can be achieved when there is enough evidence to convince consumers that agricultural plastics are increasingly problematic for the environment and necessary policies are in place and adhered to support green and sustainable initiatives. For example, a policy like providing incentives for companies to produce or import biodegradable plastic products will reduce the price of biodegradable plastic mulch or bags so that it will be affordable for farmers. Another strategic policy would be one that imposes extended producer responsibility (EPR)



for plastic manufacturers, packaging factories, or plastic packaging manufacturers in general who reside in Cambodia. One of the forms of EPR could be a recycling company that could be the off-taker of plastic waste in Cambodia. In the long run, Cambodia could consider supporting biodegradable manufacturers in the country for sustainable agriculture practices.

- ***Developing a niche customer base of early adopter farmers for biodegradable plastic mulch***

As farmers tend to be influenced by their peers, it is important to build pioneering farmers who use biodegradable plastic products as an example of success. This way, other farmers will follow suit, and the customer base can be expanded. This group can be developed through private, government, NGO programs, or a combination of these parties and will likely require incentives to adopt these new biodegradable products.

- ***Mainstreaming and standardisation of biodegradable products***

Biodegradable plastic still has different standards used to prove its biodegradability, meaning the general public is not yet on the same page on the definition of biodegradable. The fact that different products have different biodegradability claims complicated decision-making for consumers. The government then has to develop a set of standards for biodegradability, not only to make the claim justifiable and consistent but also to set a similar sense of expectation for the product in the customer. These standards can be adapted through other existing standards (i.e., EN 17033:2018, ASTM D6400-21, ISO 17088:2021).

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iDE is a global team of 1,200 changemakers coming from diverse backgrounds within international development and the private sector. What we all have in common is the belief that one entrepreneur can change their community and millions can change the world. Our work stands out in the international development arena. We are driven to end poverty but not through simple handouts of supplies or cash. We empower the people as we believe that everyone has the ability to increase their livelihoods and build long-term resilience of their own accord. We empower through training and providing connections to suppliers and customers.

In Cambodia, iDE has been growing prosperity with rural households since 1994, powering entrepreneurs and social enterprises and facilitating inclusive and resilient market systems development in the agriculture and WASH sectors. We have recently expanded our focus on climate and resilience through climate-nexus programming along with research and pilots in clean cookstoves and solid waste management, concentrating on plastic waste recycling and circularity. To date, iDE Cambodia has reached over 1.2 million households and roughly 5.8 million people.

cambodia@ideglobal.org
www.ideglobal.org/country/cambodia



Resilience Development Initiative (RDI) is an Indonesian think tank initiative that focuses on issues such as disaster and climate resilience, renewable energy systems, gender equality, children's welfare, and sustainable development, among others. RDI plays a part in contributing to the body of knowledge on sustainable development, social issues, and resilience research studies.

rdi@rdi.or.id
www.rdi.or.id