REPORT

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A STUDY OF HORTICULTURE PLASTIC PRODUCTS: ENVIRONMENTAL IMPACT IN CAMBODIA

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This study was 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.

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SUMMARY

Agriculture has been the backbone of the Cambodian economy for centuries. In recent years, the sector has undergone a period of rapid growth and transformation, driven by a number of factors, including increased investment, improved productivity, and expanded trade. The horticulture sector in Cambodia is an important part of the agricultural economy due to a rapidly increasing urban consumption demand for fruits and vegetables. In spite of this, horticultural plastic products may have a negative environmental impact if the waste management is not done properly. This study was conducted to estimate the use of horticultural plastics and plastic waste management by farmers in Cambodia. The results showed that plastic mulch is the most commonly used horticultural plastic, followed by driplines and plastic nets. The estimated potential horticultural plastic usage is approximately 515,450 tonnes/year, which accounts for up to 12% of waste generation throughout Cambodia. Farmers agree that improper plastic waste management could negatively affect the environment and health of the community, but the majority of farmers burn or bury their plastic waste due to the lack of waste management infrastructure in rural areas. The study also found plastic remnants in horticultural fields in the form of macroplastics and microplastics, which can cause negative impacts on human health and the environment. The study suggests several possible interventions to reduce the negative impact of horticultural plastics, including increasing the circularity of plastic products and developing alternatives for agricultural plastic products. These interventions can be made possible by multistakeholder collaboration, namely farmers, governments, private sectors, and NGOs.

INTRODUCTION

Agriculture has been the backbone of the Cambodian economy for centuries. In recent years, the sector has undergone a period of rapid growth and transformation, driven by a number of factors, including increased investment, improved productivity, and expanded trade. Farming contributed 21% of Cambodia's GDP in 2019, with a number of agricultural holdings of 1.726 million households (NIS, 2020). Most Cambodian citizens live in rural areas, and 77% of rural households rely on agriculture, fisheries, and forestry for their livelihoods (NIS, 2021).

Likewise, the horticulture sector in Cambodia is an important part of the agricultural economy due to a rapidly increasing urban consumption demand for fruits and vegetables. Horticulture input plays a critical role in improving the quality and quantity of crop yield. These horticulture inputs include seeds, pesticides, fertilisers, plastic mulch films, and irrigation systems, which result in plastic waste. However, waste management of this horticulture plastic is still a less prominent problem in rural and peri-urban areas, particularly plastic mulch. In 2022, Cambodia produced more than 4 million tonnes of waste per year, with the composition of 60% organic waste, 20% plastic bags, and 20% other solid waste (Khmer Times, 2022).

A substantial amount of plastic is involved in the horticulture process, such as plastic mulch, plastic bags, plastic sacks, driplines, plastic packaging, plastic net, and many more (Figure 1), as it is used by the farmers to help increase productivity. Plastic mulch, one of the main plastic products used in horticulture, is mostly made from polyethylene (PE) or low-density polyethylene (LDPE). The plastic mulch film can improve water use efficiency, prevent weed growth, and reduce soil erosion, improving crop yield (FAO, 2021).

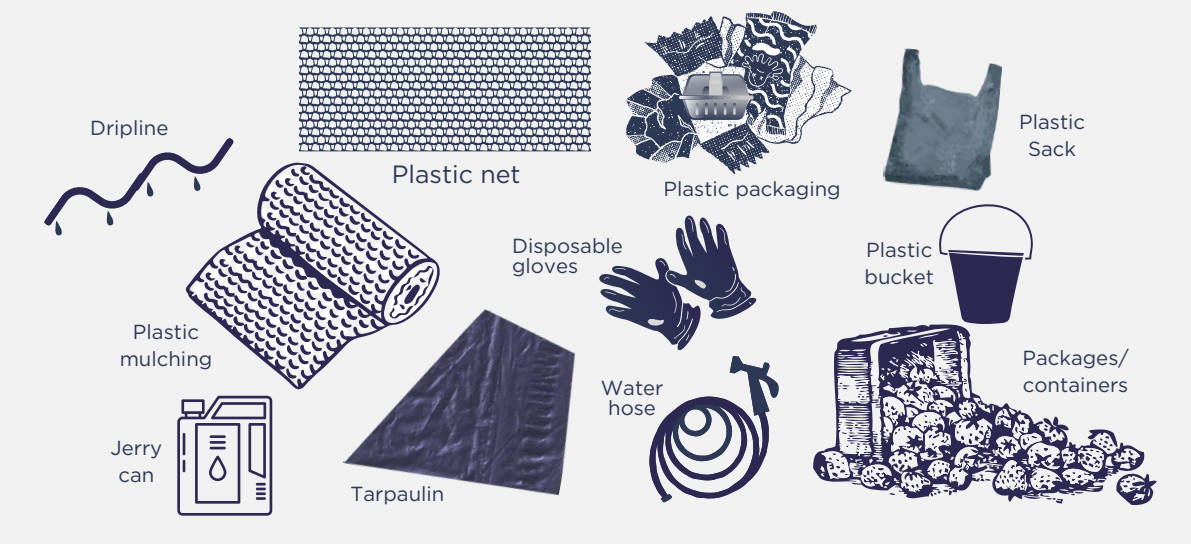

Figure 1. Agricultural plastic in Cambodia

Recently, there has been an increasing concern over macro- and microscopic plastic residues in the soil, which is a threat to sustainable horticulture and food safety. Many alternative and innovative approaches have been developed to address this issue. For instance, some companies are thinking about ways to produce compostable plastic or recycle plastic waste into reusable products.

This study aims to understand the environmental impact from the waste of horticulture plastic usage in Cambodian farmland. In particular, this study aims to understand the current practice of plastic management in the horticulture sector and provide the necessary recommendations needed to make the horticulture practice more sustainable. This can include using biodegradable plastics or finding alternative materials that are less harmful to the environment.

METHODOLOGY

The study combined qualitative and quantitative approaches and was carried out by RDI and iDE Cambodia from October to December 2022. The overview of the methodology is shown in Figure 3. The location of the study is in 5 provinces of Cambodia, namely Battambang, Banteay Meanchey, Oddar Meanchey, Siem Reap, and Kandal, with the scope of this study specifically discussing horticultural farming. CSmart works in 3 provinces: Siem Reap, Banteay Meanchey, and Oddar Meanchey. The provinces of Battambang and Kandal were included in the study because they are highly productive horticultural production regions in Cambodia. The total area of horticulture farms in Cambodia is 27,872 ha (NIS, 2020). Data collection was conducted by desk review, in-depth interview, questionnaire, observation, and soil sampling. The findings of this study aim to identify horticultural plastic's potential positive and negative impacts, with plastic mulch as the product to be sampled.

We interviewed government ministries and departments responsible for environment and agriculture at national and provincial levels. In addition, we collaborated with five NGOs focused on agriculture and waste management. We also engaged with United Nations agencies such as the FAO and UNDP.

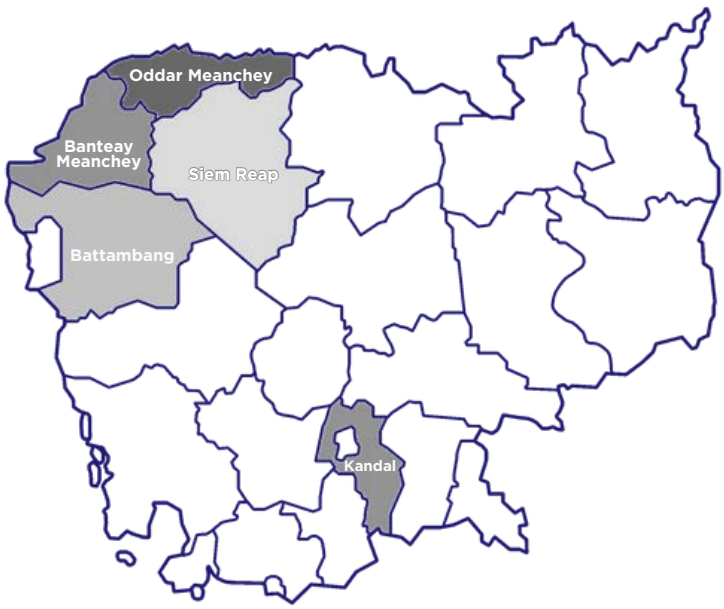

Figure 2. Study Location

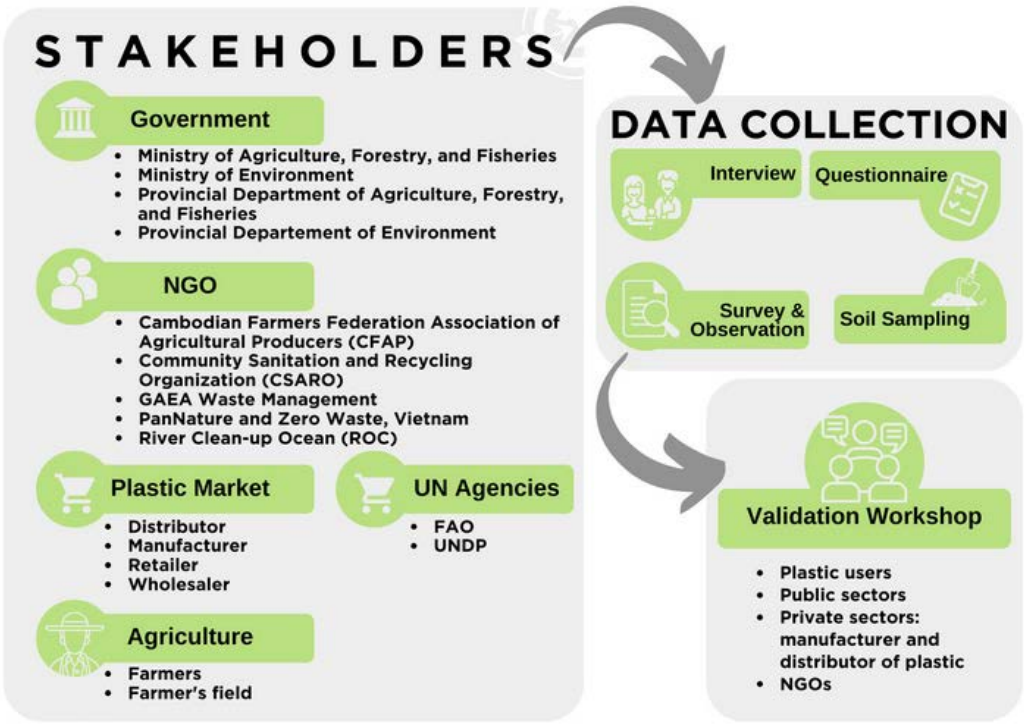

Figure 3. Methodology of the Study

Our in-depth interviews included 80 farmers, four plastic wholesalers, six plastic retailers from five provinces, and four plastic manufacturers in Southeast Asia and Australia. We collected questionnaire responses from a total of 121 respondents across the provinces, with a target of 24 respondents per province, using homogeneous non-probability sampling. In the end, we held a workshop to validate the study findings and raise awareness among stakeholders about the impact of agricultural plastic usage and possible courses of action. It also aspires to be a platform for future collaboration among governments, private, non-governmental organizations, and communities in advancing sustainable production and welfare enhancement.

KEY STUDY FINDINGS

Attitude and behaviour of farmers toward horticultural plastics

The current usage of horticultural plastic is estimated based on a survey of 121 respondents from five (5) provinces in Cambodia. The result shows that the most significant contributor to plastic usage in horticulture is plastic mulch, followed by driplines and plastic nets (Table 1). Plastic mulch usage intensity[1] is estimated at 235 kg/ha/year, and dripline is at 228 kg/ha/year. Similar to plastic mulch, driplines in Cambodia were made from PE, which is difficult to recycle after being broken down into pieces.

[1] *Usage intensity is the product usage rate (average product used in a certain duration) divided by average area*

The usage duration of plastic mulch is mostly less than six months (Figure 4), while driplines vary. As farmers practise, some plastic mulch can be used for up to two (2) to three (3) crop cycles and at least three (3) crop cycles for driplines. The variation in usage duration depends on the quality of plastic used and the crop maintenance practice of the farmers. For instance, better-quality driplines can be used up to a few years.

TABLE 1.

ESTIMATION OF POTENTIAL AGRICULTURAL PLASTIC USAGE INTENSITY FOR HORTICULTURAL FARMER

PLASTIC PRODUCT	PERCENTAGE OF USERS (FROM 121 FARMERS)	USAGE (KG/YEAR)	POTENTIAL PLASTIC USAGE INTENSITY (KG/HA/YEAR)	POTENTIAL WASTE GENERATED (%)
Plastic mulch	67%	198	235	38%
Dripline	75%	198	228	37%
Plastic net	45%	58	80	5%
Water hose	58%	20	37	5%
Plastic containers	50%	24	31	5%
Plastic packaging	94%	4	6	1%
Tarpaulin for drying	46%	4	4	0.65%
Plastic buckets	87%	1	1	0.22%
Tarpaulin for greenhouse	5%	0.62	0.89	0.14%
Plastic sack	35%	0.35	0.51	0.08%
Jerry can	33%	0.39	0.43	0.07%
Disposable gloves	52%	0.12	0.15	0.02%

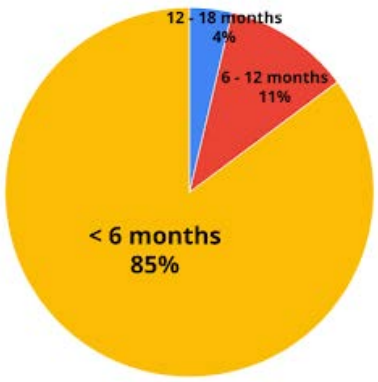

Figure 4. Duration of plastic mulch usage

The amount of plastic used in farmland varies greatly depending on the farming practice. For comparison, plastic mulch intensity in a maize site in Northwest China is around 60 kg/ha/year, while in a cotton site, it amounts to 150 kg/ha/year (Meng, et al., 2020).

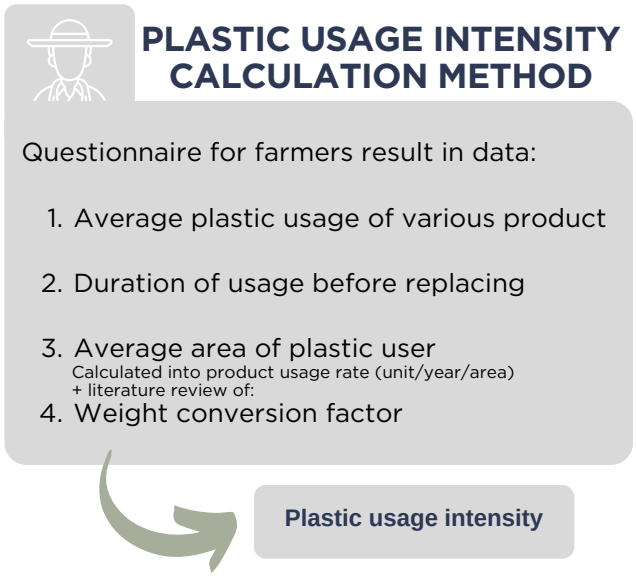

Figure 5. Calculation method of plastic usage

Based on our plastic usage intensity and the total area of horticulture farms in Cambodia, which is 27,872 ha (NIS, 2020), the potential horticultural plastic usage is approximately 515,450 tonnes/year. This takes up to 12% of waste generation throughout Cambodia.[2] The estimated number of horticultural waste generated in Cambodia may contribute to the total plastic bag waste generated in the country (20% of total waste, according to Khmer Times, 2022)

Cambodian farmers generally agree that plastic use in horticulture harms the environment. Most farmers agree that improperly managed plastic could affect the environment and health of the community (Figure 6).

> *Plastic mulch usage intensity is estimated at 235 kg/ha/year, and dripline is at 228 kg/ha/year. Similar to plastic mulch, driplines in Cambodia were made from PE, which is difficult to recycle after being broken down into pieces.*

[2] *Rough estimation from sampled population, extrapolated to include all Cambodian regions**

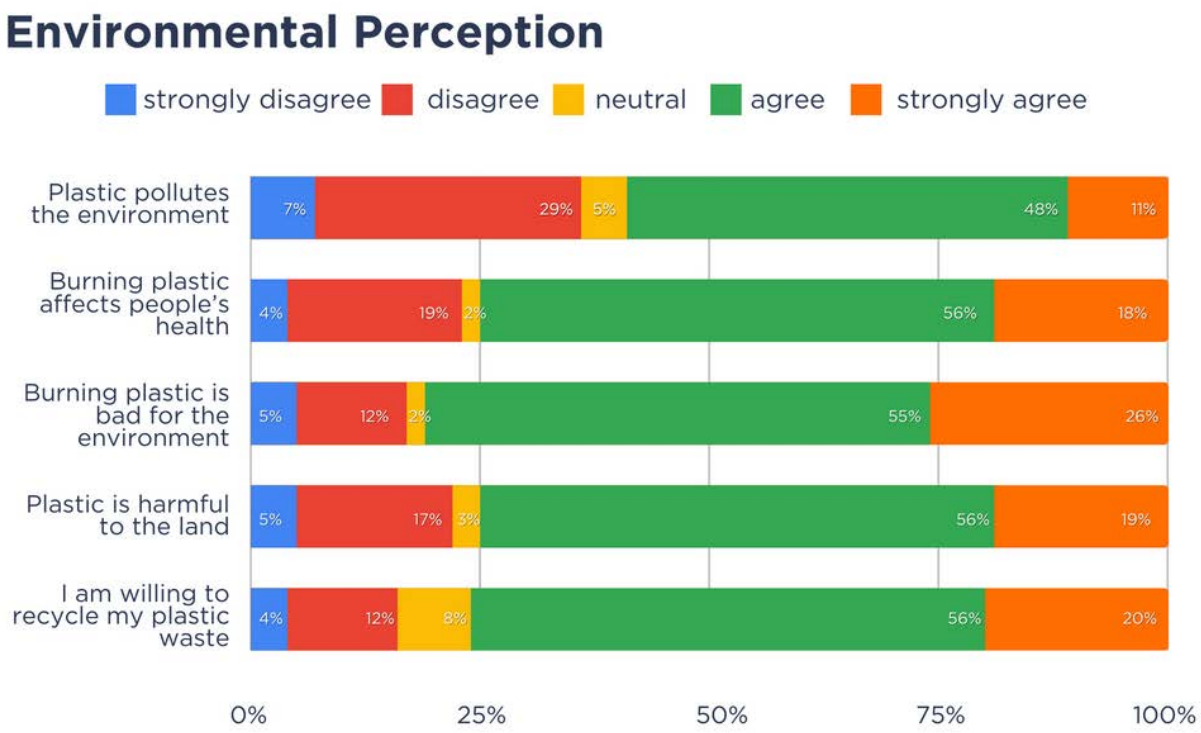

Figure 6. Environmental Perception of Farmers Regarding Plastic

> *95% of farmers burn their plastic waste.*

Plastic waste management in horticultural sector

Burning and burying plastic waste are the two most common ways most farmers do to manage their plastic waste since waste management institutions are still uncommon in rural areas. In the Figure 7, it can be seen that 95% of farmers burn their plastic waste. This finding is also supported by interviews with the department of environment in each province. With most of the infrastructure for waste management being developed in urban areas, it is possible to transport waste from rural areas to the nearest waste management facilities or landfill. However, the cost of the waste management ecosystem, particularly transportation, needs to be considered.

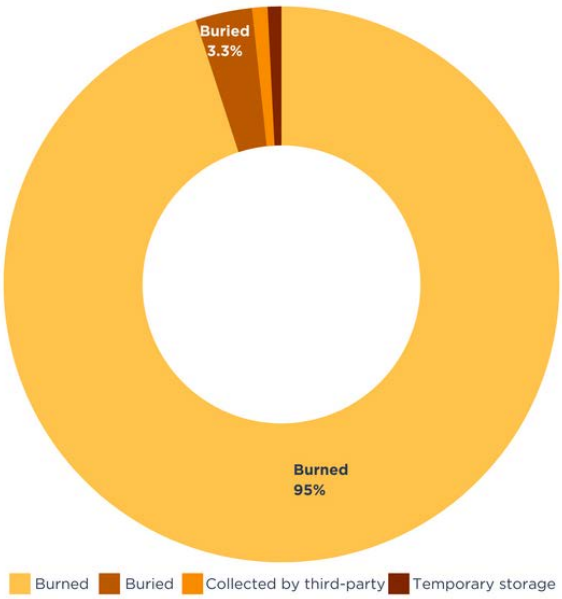

Figure 7. Plastic Waste Management in Horticultural Sectors in Area of Study

Remnant plastic found in horticultural fields

Plastic degrades to macroplastics (MaPs) to microplastics (MiPs) (0.1 to 5 mm) and even nanosized particles (<100 nm) over time. An analysis of microplastics in the horticulture field in five (5) provinces in Cambodia found plastic in the form of fragments and fibre (Figure 8). Fragments dominated the shape of microplastic in all sample sites (95% from samples).

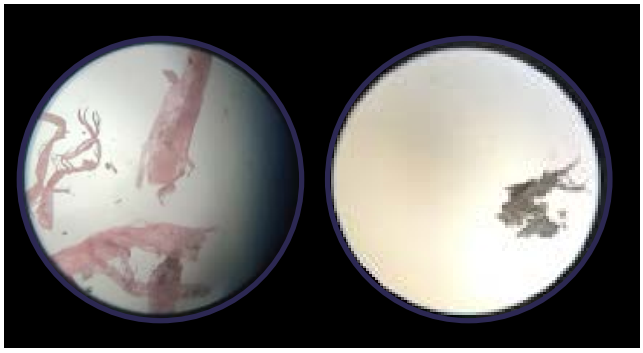

Figure 8. Microplastic from Soil Sampling (left: plastic fibre; right: plastic fragment).

Based on the lab results using FTIR (Fourier Transform Infrared) spectroscopy (Figure 9), the samples show the presence of C-H bonds, the main constituents of Polyethylene (PE) and Polypropylene (PP), which might have originated from plastic mulch and dripline.

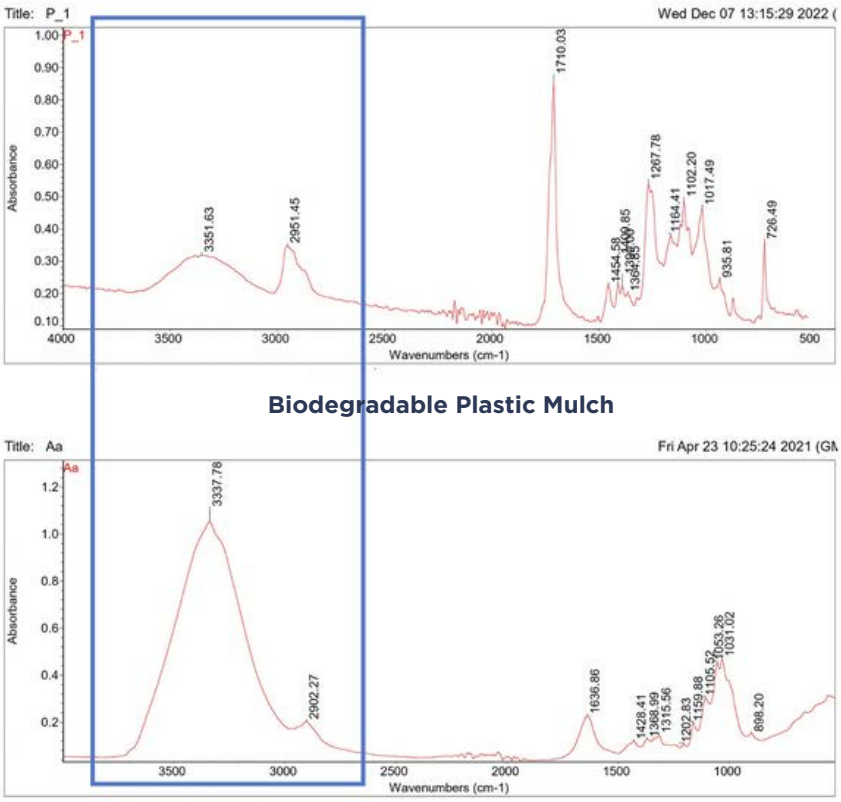

Figure 9. Difference between Biodegradable Plastic Mulch and Conventional Plastic Mulch

The number of plastic remnants from soil analysis from each layer of five (5) provinces' sample sites in Cambodia in this study is shown in Figure 10. In the top layer (0-10 cm depth), the quantity of macroplastics measured 28.6 x 10^4 pieces per hectare, while the quantity of microplastics measured 76 pieces per kilogram. In the second layer (10-20 cm depth), the amount of macroplastics observed was 94.6 x 10^4 pieces per hectare, with 61 pieces of microplastics per kilogram. Furthermore, in the third layer (20-30 cm depth), the quantity of macroplastics found was 3.7 x 10^4 pieces per hectare, alongside 32 pieces of microplastics per kilogram.

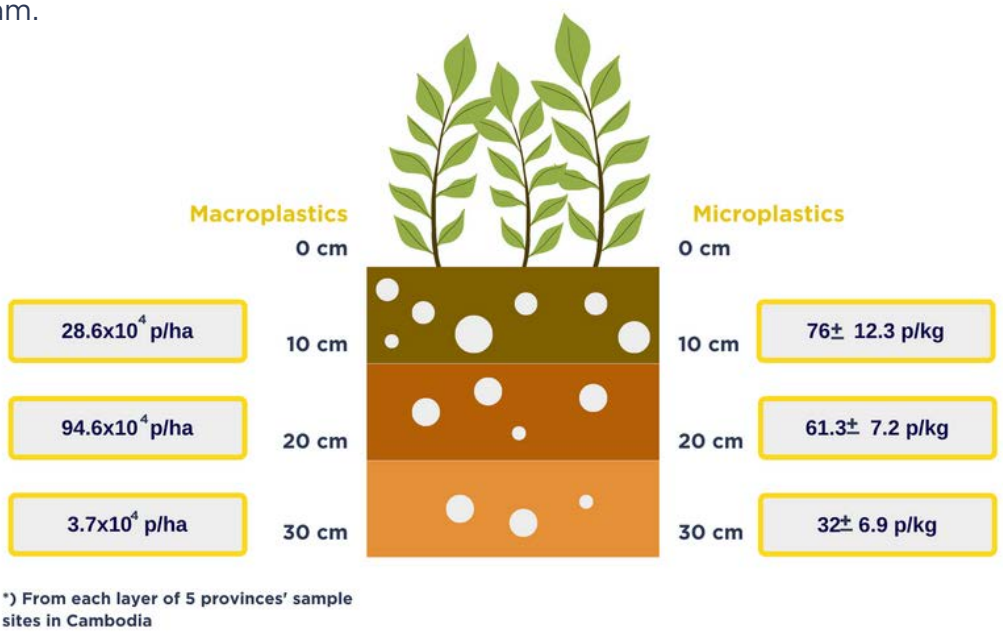

Figure 10. Visualization of Macro- and Microplastic Analyzed in the Study

Discussion

Environmental impact analysis

Burning and tilling back horticultural plastic adversely impacts the environment and people's health. Most horticultural plastic waste is from plastic mulch and driplines based on polyethylene, a fossil-based material. Polyethylene material is very difficult to be biodegraded, resulting in accumulation of macroplastic to microplastic in the environment. Table 2 presents a comparison between the abundance of macroplastics (MaPs) and microplastics (MiPs) found in our study and those reported in other studies.

Burning plastic can lead to the release of many air pollutants and hazardous byproducts, including heavy metals, dioxins, and other substances that can be inhaled by farmers and local communities, as well as deposited into plants, which could harm human health if the plants are ingested by livestock or consumed directly (Pérez-Reverón, et al., 2022) (Figure 11).

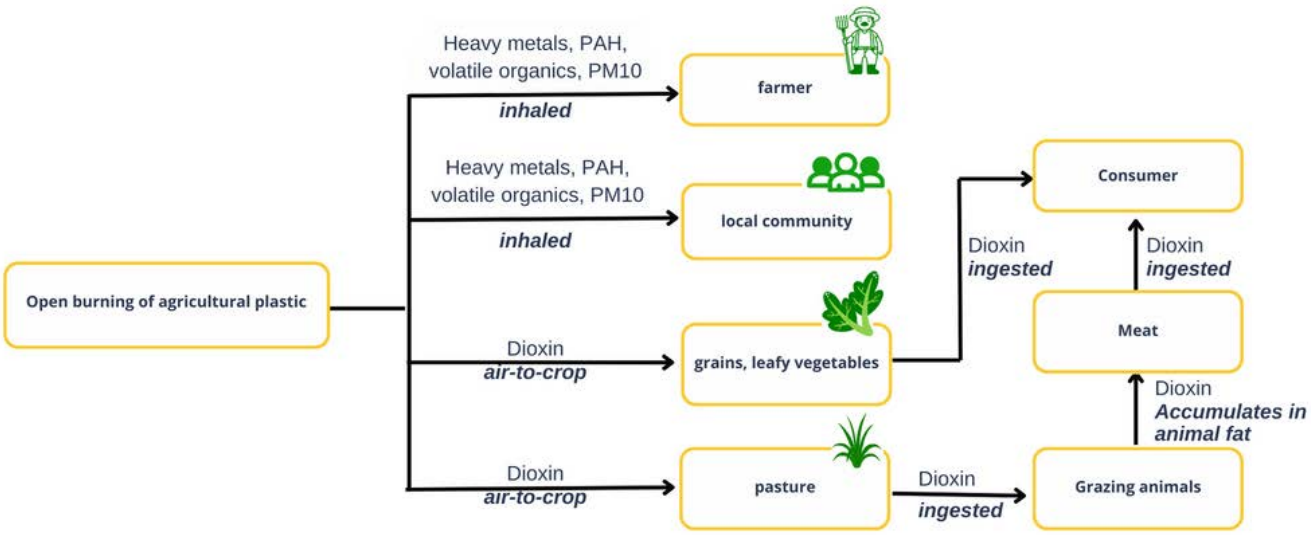

Figure 11.
Pathways of Exposure to Pollutants from Burning Agricultural Plastic

Tilled or buried plastic may give adverse impacts in the long run. As time passes, current macroplastic remnants in the field can turn into microplastics and further reduce soil quality. The plastic remnants are abundant on the top part of the soil and within the topsoil, which contains most of the ground's nutrients and fertility. Plastic contamination in topsoil can lead to the disturbance of soil biota (such as worms and microorganisms), decrease nutrient uptake of plants, reduce the soil water-holding capacity, and finally, accumulate plastic in plants and other organisms (Gomiero, et al., 2019). The abundance of macroplastic in our studies is equivalent to those in other Chinese field sites where plastic mulch film has been employed for a comparable period of time (Table 2). The average abundance of microplastics in the surface soil at our experimental location was 76 ± 12.3 ($p.kg^{-1}$) (0-10 cm), 61.3 ± 7.2 ($p.kg^{-1}$) (10-20 cm), 32 ± 6.9 ($p.kg^{-1}$) (20-30 cm), respectively (Figure 10). The figure was lower than or comparable to most prior studies of plastic film mulched land (Table 2). Nonetheless, the lower concentration of microplastic is due to the comparable shorter duration of plastic mulch usage (3-4 years), hence in the longer term, the microplastic concentration could be higher from the degradation of existing macro plastic in the soil.

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TABLE 2.

COMPARISON OF MACRO- AND MICROPLASTIC ABUNDANCE WITH OTHER STUDIES

Soil Source/ Soil Type	Duration of Mulching	Country	Abundance of MiPs	Abundance of MaPs	Reference
Vegetable fields	20 years	China	78.00 ± 12.91 item kg^{-1}		Liu et al. (2018)
Maize fields	32 years	China	8885 particles/kg		Li et al. (2022)
Farming soil	30 years	China	2200 particles·kg^{-1}	56.7 x 10^4 to 264.7 x 10^4 p·ha^{-1} (Number) 53.7 to 108 kg·ha^{-1} (Mass)	Meng et al. (2020)
Agricultural field	Mostly 3-4 years	Cambodia	76 ± 12.3 61.3 ± 7.2 32 ± 6.9 (p.kg^{-1})	3.7 x 10^4 to 28.6 x 10^4 p·ha^{-1} (Number) 74.1 to 339.3 kg·ha^{-1} (Mass)	This Study

Interventions to reduce environmental impacts and drive sustainability

As mentioned previously, horticultural plastic in Cambodia could produce waste of 515,450 tonnes/year, the majority of which will be burned or buried due to limited circularity. This leads to a high potential for plastic pollution in agricultural soil and air. Therefore, the usage of low-quality plastic mulch is detrimental. Increasing the circularity of plastic products and developing biodegradable agricultural plastic products could be a solution to reducing the impact on the environment and human health. This includes improving rural waste management and its regulation.

The government of Cambodia has developed policies and regulations to reduce plastic waste. The Municipal Solid Waste Management Policy 2020-2030 aims to improve solid waste and plastic management in the country (World Bank, 2023). Additionally, the government has implemented a ban on single-use plastics in some areas (UNDP, 2023).

> *Burning plastic can lead to the release of many air pollutants and hazardous byproducts, including heavy metals, dioxins, and other substances that can be inhaled by farmers and local communities.*

Increasing circularity of plastic products

Reusing plastic products on the farm can be a great way to reduce waste. Plastic products like containers, buckets, and bottles can be cleaned and repurposed for a variety of agricultural tasks. For example, plastic containers that previously contained non-hazardous material can be used to store seeds or fertiliser, while buckets can be used to carry water or feed. In this effort, CSmart farmers have reused dripline as the net for vine crops or for trellising, fencing, and sometimes making useful implements, e.g. baskets. By reusing plastic products this way, farmers can reduce their environmental impact while making the most of their resources.

Improving the durability and recyclability of agricultural plastic products is also a critical step toward sustainable farming practices. One way to achieve this is through designing durable plastic products such as mulch, greenhouse covers, irrigation driplines, and nets that are easy to collect, clean, and recycle. The design of these products should consider factors such as material selection, product shape and size, and ease of dismantling. It is also essential to establish collection and recycling programs for these agricultural plastics. The CSmart project has encouraged farmers to use good quality yet affordable plastic mulch film and drip irrigation systems instead of the lowest price/quality. The CSmart project has also continued to explore recycling opportunities for agricultural plastic waste. Establishing collection schemes between farmers and stakeholders can be implemented by incentivising farmers to collect their waste and Extended Pro-

> *The usage of low-quality plastic mulch is detrimental. Increasing the circularity of plastic products and developing biodegradable agricultural plastic products could be a solution to reducing the impact on the environment and human health.*

ducer Responsibility (EPR) deployment. EPR schemes can reduce the burden on local waste management systems and prevent plastic waste from ending up in landfills or the oceans by requiring manufacturers to take responsibility for the waste generated by their products. Furthermore, this should benefit producers because they can use the waste as a resource for their new product, increasing circularity.

Based on the Cambodia Sub-Decree No. 113 on Municipal Solid Waste Management, the waste collection, transportation, storage, recycling, and dumping services are the responsibility of the municipality, city, and district authorities with the support and coordination from provincial authorities. However, due to limited management capacity, financial allocation, and personnel, the authorities have transferred the service to private operators in many cities and districts (Pheakdey et al., 2022). The efforts made by the Ministry of Environment are to set the new amendment of Sub-Decree No. 168 on Plastic Management that will cover a much wider variety of plastic, such as agricultural plastic, healthcare plastic, etc. The purpose of this sub-decree is to make an improvement on reducing the import, production, distribution, and use of plastic products to ensure public health, environment, and aesthetic protection. According to the Ministry of Environment, currently, there are small business recycling facilities in 24 locations across Cambodia. The emerging actors of recycling should be supported by establishing better waste management services in Cambodia.

The current practice of waste management in Cambodia mainly relies on landfills (44%), while recycling, incineration, and composting share 4%, 4%, and 2% of waste generation, respectively. In 2021, 164 landfills were operating across the country. Still, most were poorly designed, except the Dangkor Landfill in Phnom Penh, which incorporates advanced techniques and a leachate drainage system (Pheakdey et al., 2022). Some infrastructure needs to be provided to run proper waste management in rural areas, such as collection points, waste transportation

photo source: RDI - IDE

photo source: iDE

schemes, and recycling facilities. In Cambodia, a few emerging waste management services are available, including GAEA Waste Management and Lim Vanny Recycling Centre. GAEA Waste Management is involved in various activities such as municipal solid waste collection, disposal, and management in major cities like Phnom Penh and Siem Reap, as well as in Kampong Thom and Banteay Meanchey provinces. Additionally, they are currently engaged in pilot projects focused on recycling initiatives, including recycling plastic bottles. Another notable facility is the Lim Vanny Recycling Centre, which specializes in recycling waste into valuable raw materials that can be used for producing a wide range of recycled plastic items such as chairs, brooms, baskets, and rice sacks.

> *There are small business recycling facilities in 24 locations across Cambodia. The emerging actors of recycling should be supported by establishing better waste management services in Cambodia.*

Based on interviews with the Department of Environment in each province, advocacy programmes to raise awareness on waste management have been initiated. For instance, in 2020, the "2020 Beautiful Banteay Srei" campaign was launched. This campaign focuses on creating model villages in Banteay Srei by cleaning up the village routinely and campaigning for environmentally friendly to boost tourism. In addition, there is the Government Body Conservation Agriculture of Cambodia Conservation Agriculture and Sustainable Intensification Consortium (CASIC) that aims to create a diverse network of organisations that have an interest in Conservation Agriculture (CA), which can address the issue of 'lack of awareness' by promoting CA practices, creating demand for CA machinery and implements and bridging the gap between the private sector and the farmers. By promoting CA practices, such as substituting plastic mulch with organic soil cover, we can also encourage the implementation of waste management practices. This is because waste management practices are closely related to conserving environmental quality in terms of managing plastic usage in agriculture. Several NGOs also have taken initiatives to raise awareness about waste management. One such organization is River Clean-up Ocean (ROC), which concentrates on the cleaning of river waste and promotes waste segregation into recyclable and non-recyclable categories. ROC's efforts aim to improve the cleanliness of rivers and reduce the pollution caused by improper waste disposal. Additionally, the Community Sanitation and Recycling Organization (CSARO) advocates for

effective waste management practices in tourism areas, islands, and cities. CSARO focuses on educating and engaging communities in sustainable waste management practices. Through their awareness-raising activities, both ROC and CSARO contribute to fostering a culture of responsible waste management in Cambodia. The United Nations Development Programme (UNDP) has focused on communication and outreach to raise awareness about plastic pollution in Cambodia. This includes public awareness campaigns to educate the public on the negative impacts of plastic pollution and the importance of waste reduction and recycling.

Developing alternatives for horticultural plastic products

The government of Cambodia has implemented policies and regulations to promote the use of biodegradable plastics. The Municipal Solid Waste Management Policy 2020-2030 aims to improve solid waste and plastic management in the country, including the promotion of biodegradable plastics (Song et al., 2009).

Redesigning conventional plastic into biodegradable plastic is one of the alternatives to address plastic pollution in the horticultural sector. FAO (2021) has several terms for bioplastic, such as biodegradable plastic, compostable plastic, and bio-based polymer plastic. Biodegradable plastic means that the plastic can be degraded by microorganisms, such as bacteria, fungi, and algae, into water, biomass, and gases, including carbon dioxide and methane. The material should be fully assimilated, leaving no residues in the natural environment. Compostable plastic is a subset of biodegradable plastic that requires specific conditions for total degradation, either by control of the environment or the removal of residual materials. Another term that is similarly used is bio-based plastic, which is generated from natural monomers formed by plants, microorganisms, and animals that can be fully or partially artificial. Bio-based plastic is not always fully biodegradable, depending on additives. Biodegradable plastic needs to be standardised and include end-of-use management to have a significant positive impact.

photo source: RDI-IDE

The UNDP has supported the development of sustainable alternatives to plastic products and promoted the use of biodegradable plastics (World Bank, 2023). Biodegradable plastic mulch has been manufactured and used in several countries, mainly developed countries. Companies like Cleanbodia are producing cassava eco-bags to reduce plastic use in the country. These bags are both biodegradable and compostable, and can last for up to six years. The bags are also said to be as strong as regular plastic, but without the chemical feel and smell that plastic often has (Inquirer, 2019). However, replacing this material with plastic mulch is difficult to implement due to several barriers.

One of the significant barriers is the price of biodegradable plastic, which can be two times more expensive than conventional plastic. Although non-biodegradable plastics are less expensive in the short run, in the long run they bring additional costs associated with waste management and reduced soil health.

The CSmart project has actively researched and trialled alternatives that avoid the problem of plastic waste, such as field trials on biodegradable mulch (Figure 10). Besides biodegradable plastic, the CSmart project has initiated using natural materials, such as rice straws for mulches. However, straw is not suitable to use in the rainy season, as problems such as plant pests and diseases in the straw arise. Not only that, using straw as mulch also competes with feedstock usage for cattle, which results in increased price of straw. Another nature-based approach is to grow cover crops to replace plastic mulch, such as cereal rye, vetches, legumes, clover, etc.

Furthermore, efforts such as training and capacity-building programs to farmers, focus on ecologically friendly practices have been done by many development projects and governments, one of which is the Cambodian Farmers Federation Association of Agricultural Producers (CFAP). For example, CFAP has programs aimed to enhance farmers' knowledge and skills in adopting sustainable agricultural methods and the impact of climate change on farms. Through research and providing education and training, these efforts will empower farmers to make informed decisions and implement practices that promote both environmental sustainability and agricultural productivity.

photo source: RDI - IDE

Figure 12.
Alternative plastic mulch trial by CSmart (left: plastic mulch film from Thailand; right: A) plastic mulch from Thailand, and B) compostable plastic mulch).

Conclusions

Agriculture has been the key contributor to Cambodia's economy for decades. Similarly, the horticulture sector in Cambodia plays an important part in the country's agricultural economy due to fast rising urban consumption demand for fruits and vegetables. However, the practice will not be sustainable due to the amount of waste generated from the plastic products used to support the horticulture activities.

According to this study, the plastic usage from horticulture activities is roughly 515,450 tonnes per year, accounting for up to 12% of garbage creation in Cambodia. Plastic mulch, driplines, and plastic netting are the most common plastic products used in horticulture activities. Unfortunately, burning (95%) and burying plastic waste are the two most common ways most farmers manage their plastic waste. This unsustainable practice was found to be polluting the horticulture soil: the concentration of macroplastic in our studies is equivalent to those in Chinese farming sites where plastic mulch film has been employed for more than two decades. Correspondingly, the high concentration of macroplastics could contribute to the high concentration of the microplastic in the coming years.

Cambodia has taken several initiatives to combat plastic pollution, including policies and regulations. These initiatives aim to reduce plastic waste, promote sustainable production practices, and protect the environment and public health. A part of the initiative is to promote the use of biodegradable plastics as a sustainable alternative to traditional plastics.

Collaboration and synergy among stakeholders are required to reduce environmental impacts and promote sustainability in the horticulture sector. The roles that can be emphasized in the plastic pollution case are as follows:

- Farmers play an important role in reducing plastic usage in their activities. They must be aware of the long-term effects on the environment and participate in measures to reduce waste. The challenges faced by farmers involve two key aspects: the market price of plastic alternatives and the need for a shift in behaviour to discourage the burning or burying of plastic waste by promoting its proper disposal at nearby waste facilities instead. Our research findings indicate that farmers are generally aware of the potential environmental and health impacts associated with improper plastic waste management in horticulture. This highlights the possibility of addressing this issue effectively if adequate waste infrastructure is made accessible to them. In addition to incentives and trainings for farmers, it may be necessary to conduct extensive research on which alternatives are best suited for the specific conditions and needs of farmers in order to promote the adoption of plastic alternatives.

- The government has the authority to implement policies that support plastic recycling, incentivize usage of single plastic alternatives, and promote research and development of plastic alternatives. In terms of waste management, the government can improve waste management services, infrastructures, and supporting policy. It is encouraging that the government is developing institutions that have the responsibility and ability to implement and oversee waste reduction and waste management initiatives, and it is encouraging to see emerging collaborations between the government, private sector, and development partners. Yet the government faces challenges in terms of human and financial resources and supporting infrastructure. As such, the financing of plastic waste management should be born together with the private sectors, through extended responsibility scheme or through plastic pricing scheme.

- The private sector, including manufacturers and distributors of plastic and waste management service providers, plays a vital role in reducing and mana-

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ging plastic waste. Important roles for the private sector include the production of plastic alternatives, ideally locally to reduce the cost of the product and therefore the sales price (e.g., biodegradable plastic and more durable plastic), drive innovation in available products and services, and develop the supply chain and supporting services for plastic waste collection, recycling, and upcycling. Nevertheless, the private sector faces a significant challenge as the demand for biodegradable plastic is not as substantial as that for conventional plastic, primarily due to its higher cost. Consequently, there is likely a crucial role for the government to play in providing support measures such as providing incentive for supplying biodegradable plastic (setting pricing scheme of conventional plastic, offering tax exemptions for biodegradable plastic) and ensuring the presence of sufficient plastic recycling facilities.

- The development sector, particularly non-governmental organisations (NGOs), plays a significant role in addressing the issue of plastic waste impact in horticulture and beyond. Their potential roles include raising awareness among farmers about the impact of plastic waste and fostering their interest in adopting more sustainable practices. The development sector can also collaborate with local authorities to establish, support, and scale initiatives that promote sustainable agricultural practices. The development sector can also act as a convener and facilitator, supporting collaboration among various stakeholders, including farmers, the government, and the private sector to promote learning, collaboration, and synergistic efforts. However, as the development sector requires development funding, it will be important to secure financial support from bilateral, multilaterals, foundations, and corporates, as well as technical support from relevant experts. The length and scale of the development sector will be helped or hindered by the availability of available human and financial resources, as such any support from the government in terms of data provision or joint coordination will accelerate the progress.

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About iDE

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 by 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, roughly 5.8 million people.

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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.

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