Agricultural Plastic Film Mulch in Southeast Asia Region and Strategies to Mitigate the Associated Environmental Concerns: A case study in Cambodia

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The importance of plastic mulch in Cambodia's horticultural sector

Agriculture has long occupied an important position in the economic and social development of southeast Asia countries. Particularly for Cambodia, agriculture remains a key engine in reducing poverty and boosting shared prosperity. About 8.5 million people work to feed the country and contribute to 22% of the National GDP (NIS, 2021a). The activity of its agricultural sector is to cover the growth and production of plants for human use, either for food, fibres, fuels, or medicines.

In general practice, a wide range of plastic products are used to help improve agricultural productivity and efficiency in this region. One of the notable plastic used in the agricultural sector is plastic mulch. It acts as a physical barrier that covers the soil surface by protecting the seedling and shoots. It works by regulating solar radiation and hydrothermal status of the soil surface, which can increase crop productivity and water use efficiency and produce high-quality crops (Gao et al., 2019). In addition, farmers become less reliant on various chemicals such as pesticides and herbicides because the protection and controlled microclimate can suppress weed growth. All of these benefits are supported by the affordable price of the material, so the use of plastic mulch is very much compelling to the Cambodian farmer from an economic perspective.

According to national statistical data, a cultivated area of vegetables in Cambodia reached 57,300 ha with a production of 682,000 tonnes in 2019 (NIS, 2021b). A wide variety of vegetables is cultivated across the country, including leafy, stem and fruit-bearing vegetables, root, bulb and tuberous vegetables, and leguminous green vegetables. Fruit-bearing vegetables such as eggplant, tomato, chili, cucumber, squash, and others, are planted on 35,000 ha (NIS, 2015). Cucumbers accounted for the largest area planted with 7,000 ha, followed by watermelon planted at 6,000 ha and chilli and pumpkin at 5,000 ha each. Due to the rapidly increasing urban consumption of fruits and vegetables in Cambodia, productivity in the horticulture sector needs to be improved to meet the local demand per province. The Cambodia Horticulture Advancing Income and Nutrition project (CHAIN) is one of the active programs to support the development of the horticulture sector in Cambodia and follows a market system approach (CHAIN, 2021). Push for use of production technologies including mulching is one of the successful interventions for market development applied by CHAIN. Hence, it is likely that the demand for agricultural plastic products will also increase to fulfill the need.

Limitations and concerns on plastic mulch

According to Le Moine (2018), mulch films represent the second-largest use of plastic films in agriculture by volume, exceeding 2 million tonnes globally. The limitation of plastic mulch, like other majority types of plastic, is designed as a single-use product. Since plastic mulch does not decompose, the large-scale application and intensive use of it will lead to an excessive amount of waste at every end of the crop harvest period. Although the exact volume of plastic mulch waste generated in Cambodia's horticulture is unknown, these items represent a 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). Since the waste collection services to landfills are still limited in Cambodia, especially in rural areas, often the first three methods of disposal are mainly chosen by the farmers. 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 (Scarascia-Mugnozza et al., 2008). Not all countries have recycling facilities, especially in most parts of southeast Asia countries. Also, many recycling centers refuse to accept plastic films with more than 5% contaminants by weight (Kasirajan & Ngouajio, 2012). Considering that agricultural plastic waste is covered with soil and crop debris (up to 50% by weight), only small parts of it are recycled.

Plastic residue accumulation in farmland

An increase in plastic mulching practices has been going on for years and is considered a major source of the plastic residue found in farmland. After its deposition in soil, plastic mulch is subject to decomposition from macro- to microplastics (MPs) and even nanosized particles (NPs) (Piehl et al., 2018; Wahl et al., 2021), having sizes between 0.1 and 5 mm and <100nm, respectively (EFSA, 2016; Hardy et al., 2018). The general mechanism of polymer degradation is triggered by exposure to ultraviolet or thermal energy under aerobic conditions (Ng et al., 2018). Photo- and thermally-initiated oxidative degradation leads to plastic embrittlement, cracking, and weakening with time (Gardette et al., 2013). Hence, the materials become more susceptible to fragmentation, generating MPs and NPs.

Biodegradation plays an important role in the ultimate fate of plastics in soil after extensive initial photo- or thermo-oxidative degradation. The mineralization of organic material by organism generate CO2 and H2O under aerobic conditions or CO2 and CH4 under anaerobic conditions (Mohan & Srivastava, 2011). However, many of the commonly used polymers, such as polyethylene (PE), polypropylene (PP), and polystyrene (PS), possess a carbon backbone that is resistant to hydrolytic and enzymatic degradation. According to Potts et al. (1973), carbon-chain backbones do not biodegrade until the molecular weight is <1000 g/mol. Meanwhile, the majority of sample polymer subjected to extensive pre-oxidation in accelerated conditions is still too high in molecular weight to be mineralized. Thus, it can only be partly biodegraded (Thomas et al., 2012). In addition, there are various less energetically expensive carbon sources that would be present in the soil. Therefore, for plastic-degrading bacteria, biodegradation of such plastic particles would be less likely to become a relevant process, resulting in the environmental accumulation of MPs and NPs.

Environmental effect of plastic mulch contamination

The accumulation and fragmentation of agricultural plastic in the terrestrial environment raise concerns for the environment and human health. In soil environments, microplastics (MPs) pose a potential threat to the survival, growth, and reproduction of soil biota that in turn threaten the biodiversity, function, and services of terrestrial ecosystems (Yu et al., 2021). Many studies use earthworms as model organisms for investigating the adverse effects of MPs in soil invertebrates because it is considered key ecosystem engineers (Jones et al., 1994) and bio-indicators of environmental quality (Fusaro et al., 2018). A study by Rillig et al., 2017 has shown that earthworm L. terrestris can be a significant transport agent of MPs in soils, likely via casts, burrows, egestion and adherence to the earthworm exterior. One of several possible implications of MPs transport down to the soil profile is that it could potentially reach groundwater. It is likely to pose a risk for human health if contaminated groundwater systems are used for drinking water purposes (Vethaak & Legler, 2021). Meanwhile, unregulated on-farm

burning can directly release hazardous pollutants into the air. Burning PE plastic mulch can release carcinogenic substances such as dioxin and other toxic particles into the air (Font et al., 2004; Valavanidis et al., 2008). Dioxin can cause reproductive and developmental problems, damage the immune system, interfere with hormones, and cause cancer (World Health Organization, 2019).

Alternate options for plastic mulch film

For agricultural plastics mulch, where recycling has a number of limitations (i.e. high contaminants, time-consuming removal, and costly recycling procedure), a better approach for transforming the current linear economy model is to replace conventional plastics with an alternative in an application where this results in lower environmental impacts. Bio-based plastic for agriculture use offers new recycling routes in waste management due to its biodegradability. Organic recycling through composting or anaerobic digestion for a biodegradable film can be left in situ to be fully biodegraded after being used, resulting in less waste and less contamination. The product of such degradation is water and CO2 (aerobic condition) or methane (anaerobic conditions), and the possible remains include residues and new biomass, which are not toxic to the environment (Siwek et al., 2019). Plastic mulch claiming to be biodegradable will have to pass certain testing to prove its degradability and eco-toxicity, where it can guarantee the product will completely biodegrade in the soil without adversely impacting the environment (Razza et al., 2020).

Biodegradable plastic mulch implementation challenges for developing countries

The main barrier to imposing biodegradable plastic on Cambodian farmers is the cost of the material, which is still relatively high compared to petroleum-based plastic. People who live in poor or developing areas are less likely to spend additional fees for environmental costs because they are still struggling with their economics and other primary concerns. If the price of biodegradable mulch is not yet competitive with the traditional one, the product should be subsidized by other parties, or additional charges should be put on the buyers (advanced environmental fees). However, it will intersect with another issue relating to policy, market competition, and economic gaps. So, this problem will never be solved with only one solution. Instead, an integrated step that involves various parties is needed.

Role of government, policymakers, and other stakeholders

I consider substituting conventional agricultural plastic with biodegradable material as the best option for sustainable agricultural practice in the long run because there are many limitations to recycling agricultural plastic waste. As biodegradable mulch film is still relatively hard to penetrate most of the country—considering its high price—a short-term solution for this is that farmers should maximize the usage of conventional plastic mulch for as long as possible. This, at least, could reduce the amount of plastic mulch waste in the value chain without eliminating its role in crop protection. In parallel, the government and other related parties should increase their level of campaign targets, which is not only to raise the environmental concerns of the people, but also to make sure that their awareness leads them to action. Education and economic stability somewhat become pre-conditions for individual actions on the environmental issue. Hence, it is important to understand that to achieve the mission, problems in those sectors also need to address in line with the agricultural plastic issue.

To reduce the negative impact of plastic mulch, every level of society in Cambodia has to join hands to do their part. These are several stakeholders with their proposed roles.

The government, as a policymaker and regulator, needs to establish legislation for extended producer responsibility

(EPR), where producers of plastic mulch have to ensure the appropriate disposal of their product and internalize the environmental cost into the price of the product.

Plastic mulch producer needs to charge the environmental cost of the product to fund the EPR schemes.

Importers, distributors, and retailers should maintain and provide information for the monitoring of the movements of products through the supply chain.

Non-Governmental Organizations have a role in facilitating the development of international regulatory instruments and capacity development of Cambodia.

Private agricultural organizations set standards for good agricultural practice. Farmers, as the users of plastic mulch, need to collect the plastic mulch from the land and manage it properly by sending it to the landfill or, if possible, to the recycling center.

Academia, in partnership with plastic mulch producers, needs to develop sustainable polymers and production methods using renewable resources at lower prices.

Disclaimer

Conclusion

The use of plastic mulch in Cambodia and other Southeast Asian countries has surged during the last few decades of its prominent advantages in crop production. But, it seems the scheme of its end-life has not yet been properly regulated, resulting in the accumulation of plastic mulch waste, which threatens human and environmental safety. Devising strategies to cope with this pollution must be based on the concept of 5–Rs, i.e., to reduce, reuse, recycle, rethink and restrain by concerted efforts of all society components. Biodegradable plastic mulch is considered the best alternative to ensure sustainable agricultural practices if the existing higher prices can be reduced to make it affordable for farmers. Ultimately, among the many problems the country has, the plastic mulch problem needs to be addressed along with education and economic prosperity as it is a pre-condition for individual actions on the environmental issue.

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Further Reading

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