Hybrid Paper Mulberry: A Climate-Resilient Option for Ecological Agriculture and Pasturage in the Yellow River Basin

KEY POINTS

- Hybrid paper mulberry (HPM) is a perennial woody fodder tree with a life span of 15–20 years. There is evidence it can provide highly nutritious and low-cost fodder for livestock.
- HPM is environmentally friendly and economically beneficial, with high benefit–cost ratios and a life cycle that fits well into the circular economy framework.
- Despite subsidies and policy support from the Government of the People’s Republic of China (PRC), the expansion of areas planted with HPM declined between 2015 and 2020. Not many farmers are willing to plant it, even with high subsidy support. Noneconomic factors are critical in farmers’ decision to plant HPM.
- Bridging the gap between lab (scientific) and land (practical), on the one hand, and policy and practice (implementation), on the other, is critical to increase the areas under HPM cultivation, particularly in the PRC’s Yellow River Basin.

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BACKGROUND

Globally, woody forage is a commonly used livestock feed. Different varieties of woody forage, depending on the native natural environment, are being developed and used as livestock fodder. Hybrid paper mulberry (HPM) has been developed indigenously in the People’s Republic of China (PRC) and promoted and used within the country. HPM is a perennial woody tree crop with a life span of 15–20 years. It can be grown in varied climatic conditions and soils, including degraded and barren lands. It also reduces soil and water erosion and improves soil quality over time. HPM is a fast-growing plant and can be harvested 2–4 times a year in temperate regions, 3–6 times in the subtropics, and 5–8 times in the tropics. Depending on the geographical and climatic conditions, annual yields of HPM range between 6 tons per mu (in temperate regions) and 10 tons per mu (in the tropics).2

Notes: In this publication, “$” refers to United States dollars. This brief was peer-reviewed by Darline Lim, Environment Specialist (Natural Capital Investment), Climate Change and Sustainable Development Department, Asian Development Bank (ADB).

1 A mu is a Chinese unit of measure (1 mu = 0.067 hectares).
HPM is used as livestock feed as it contains nutrients beneficial to livestock. HPM silage has a dry weight crude protein content of 19%, crude fiber content of 63%, and crude fat of 5%. These content values are, in most cases, higher than those of alfalfa.

Given its environmental and nutritional benefits, planting HPM is a good land-use option to address competing demands on land to provide food for both human and livestock populations in the PRC. In this regard, the Institute of Botany at the Chinese Academy of Sciences has focused on studying native plant resources to develop paper mulberry. Using hybrid vigor (outbreeding enhancement) and space-carrying capacity methods, the institute successfully bred a woody, high-protein, and functional variety of HPM. This innovation is a substitute for grain as feed. HPM also fits into the circular economy system of production, fodder, processing, and feed. In other words, HPM promotes an integrated ecological agriculture technology system for forage-tree-based livestock production, known as the “paper mulberry–feed–livestock system.”

HPM is also known to provide economic benefits through improved quality of poultry products (translating into greater quantity and higher selling price), reduced cost of livestock feed, and increased farm income. Given its environmental and economic gains, in addition to its resilience to grow on degraded lands, HPM was promoted by the Government of the PRC in the Yellow River Basin region between 2015 and 2020 through farm subsidies, market support, and industry promotion. The government provided poor households with subsidies for land-use shifts from grains to feed cultivation. Through the agriculture and poverty alleviation funds, an HPM industry value chain was developed, focusing on (i) promoting the economic, ecological, and poverty alleviation benefits from the links between HPM and animal husbandry; and (ii) strengthening the mechanism for improving the sustainable development capabilities of poor households.

The Asian Development Bank (ADB) technical assistance project on paper mulberry production in the Yellow River Basin prepared a policy strategy (footnote 2), which demonstrates the benefits of HPM through piloting in selected counties, alongside household subsidies, technology transfer, and market support systems. After being implemented for 5 years, the subsidy program was discontinued. The processing industry took up HPM farming and processed raw fodder into feed (e.g., pellets, powder). Despite multiple benefits and advantages, including strong support from the government, farmers’ response to the expansion of the HPM areas has been lukewarm. In fact, areas planted with HPM drastically declined in most counties as soon as the government support programs ended. Given the value of sustaining HPM in the context of environment, livelihood, and poverty alleviation, it is important to understand the process of adoption and nonadoption by farmers.

The policy and promotional interventions to expand areas under HPM cultivation in the Yellow River Basin have had differential impacts over the past years. HPM’s economic and environmental benefits have been observed in rural areas, including its contribution to improving household livelihoods and alleviating poverty. Drawing on the available narratives from surveys of three selected pilot counties (Table 1), this policy brief identifies the potential benefits of HPM at the household, industry, and end-user levels.

Table 1: Survey Details of Selected Pilot Counties

<table>
<thead>
<tr>
<th>County / Province</th>
<th>Household (Farmer)</th>
<th>Industry</th>
<th>End User</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lankao County, Henan Province</td>
<td>166</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Pu County, Shanxi Province</td>
<td>161</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Fuping County, Shaanxi Province</td>
<td>158</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>485</td>
<td>4</td>
<td>38</td>
</tr>
</tbody>
</table>

Source: Asian Development Bank estimates.

Based on the economic and environmental interlinkages of the HPM life cycle, this policy brief offers a rationale for promoting HPM in the Yellow River Basin, with the help of the circular economy framework. The objective is to examine and understand the reasons for the subdued response of farmers to expanding areas under HPM cultivation using a detailed field study. The brief also provides insights into the possible constraints and policy options for the sustained promotion of HPM. These insights may help guide the various line departments and agencies involved in promoting HPM in the Yellow River Basin.

CIRCULAR ECONOMY AND CLIMATE CHANGE: POTENTIAL USE OF HYBRID PAPER MULBERRY

Circular Economy Framework of Hybrid Paper Mulberry

The life cycle of HPM reflects an integrated system of the circular economy approach, which ensures environmental sustainability without compromising economic sustainability. Adopting the circular economy is fundamental for achieving climate change targets. While the agriculture sector contributes substantially to

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greenhouse gas emissions, application of the circular economy to the agriculture production process has been limited as the circular economy framework is mostly used in the construction and manufacturing sectors.

HPM’s life cycle fits naturally into the circular economy framework (Figure 1).

Figure 1: Simplified Circular Economy Framework of the Hybrid Paper Mulberry Production Cycle

HPM = hybrid paper mulberry.

HPM is produced and consumed at three levels—household, industry, and end users. Farmers produce HPM, which is consumed at the households and sold in the market either for direct consumption or for processing. HPM can be industrially processed into dry fodder, pellets, and powder. These processed products are consumed by end users (e.g., dairy and poultry farms, piggeries). While benefiting from the consumption of HPM processed products through enhanced productivity and quality of produce (milk, meat, eggs), end users use manure as a by-product, which helps improve soil quality in the long run. Soil replenishment completes the cycle and improves the environmental and economic sustainability of the agriculture system.

The HPM feed industry effectively addresses issues related to insufficient protein levels, excessive agricultural residues and antibiotics, and fecal source pollution. However, externalities may arise in the form of greenhouse gas emissions from the production processes. The low-input production of HPM, in conjunction with its health and environmental benefits, could limit the extent of negative externalities (Box 1). Addressing these negative externalities would further enhance the environmental benefits of HPM production.

Box 1: Health and Environmental Benefits of Hybrid Paper Mulberry

A number of scientific studies and practices have identified the following health, environmental, and economic benefits of hybrid paper mulberry (HPM):

(i) HPM is protein-rich with 18 amino acids. It is a medicinal and edible variety and is rich in functional bioactive substance. Because of its high flavonoid content, HPM has anti-inflammatory and disease-resistance properties, thereby reducing the need for drugs and aiding in the production of high-quality milk, meat, and eggs.

(ii) HPM is fast-growing and high-yielding. The produce from 1 acre can be processed into over 2 tons of crude protein powder, which is equivalent to 7 acres of soybeans or 5 acres of alfalfa in terms of net crude protein content. Thus, HPM reduces the pressure on resources and cost of fodder.

(iii) HPM can survive in poor soil conditions, drought, pests, and high salinity. It can thrive in areas with an annual precipitation of 300 millimeters or less, as well as in floodplains, rocky desert regions, and severely saline–alkali soils.

(iv) HPM can be continuously harvested for over 15 years without disturbing the soil, effectively preventing soil erosion.

(v) The cultivation process of HPM does not require pesticides or herbicides, and its feed processing does not involve the use of antibiotics or other additives. This ensures antibiotic-free feed and allows for the on-site application of livestock and poultry manure as fertilizer, thereby reducing pollution to the soil and surrounding environment.

(vi) HPM can be harvested in the same year with high returns. Average annual income can be as high as CNY3,000 per acre. This is much higher than that of silage corn (CNY1,450/acre/year) or alfalfa (CNY1,800/acre/year). The value added after processing is much higher.

Climate Resilience of Hybrid Paper Mulberry

As a perennial crop, HPM continues to produce for about 15–20 years without putting any pressure on soil and water resources. HPM can be grown under conditions of low rainfall (i.e., 300 millimeters or less) and in degraded lands, with minimum external inputs. It can withstand extreme weather conditions associated with climate risks. Planting HPM can improve household resilience through water conservation, enhanced soil quality, and lower costs for chemical fertilizers. Thus, HPM strengthens the natural resource base and reduces the strain on household financial resources. HPM is a nutritious green fodder for household livestock, which would help strengthen the household economy and establish healthier livestock–crop sector linkages. In the long run, this would contribute to more climate-resilient farming.

PROMOTING HYBRID PAPER MULBERRY IN THE PEOPLE’S REPUBLIC OF CHINA

Hybrid Paper Mulberry Poverty Alleviation Project

Between 2015 and 2022, the Government of the PRC adopted a policy promoting HPM as a long-term livestock development strategy to enhance rural livelihoods and ameliorate poverty. Several policy initiatives, promotional activities, awareness-raising campaigns, technical support, and market access were introduced as part of the strategy. Promotional activities included campaigns for high-quality development of the livestock sector and the inclusion of HPM as a new forage variety. The Ministry of Natural Resources, the Ministry of Agriculture and Rural Affairs, the National Development and Reform Commission, and the National Forestry and Grassland Administration were tasked as joint promoters of the HPM poverty alleviation project. As part of awareness building, the Poverty Alleviation Office of the State Council established the National Paper Mulberry Poverty Alleviation Leading Group and its office in 2017. Over 5 years (2017–2022), the leading group held five national on-site observation exchanges and technical training meetings and two national paper mulberry poverty alleviation promotion meetings and seminars. In addition, the poverty alleviation project committed divisions and personnel from central departments and provincial poverty alleviation departments to promote the project (footnote 2).

The Poverty Alleviation Office of the State Council and the Ministry of Science and Technology selected 35 technical experts, including 11 academics, to provide technical support in variety cultivation, seedling propagation, tree cultivation, feed processing, and livestock and poultry breeding. These experts, together with the four academic workstations for the HPM industry, were expected to provide strong technical support for the poverty alleviation project. The Ministry of Science and Technology initiated the national research and development plan to promote key technologies in the HPM industry. This improved the set of solutions for the high-quality industrialization of HPM. Inclusion of HPM stems and leaves into the Feed Raw Material Catalog helped establish the legal status for HPM to enter the fodder markets in 2018. Furthermore, the compilation of HPM feed standards for pigs, cattle, sheep, donkeys, rabbits, chickens, ducks, geese, and fish helped open up markets and address the low or insufficient availability of crude protein feed.

Expansion of the Hybrid Paper Mulberry Areas During and After the Pilot Programs

Five years of pilot programs and promotional activities appeared to have helped increase the areas under HPM cultivation in several counties. HPM was planted in more than 1 million mu (66,667 hectares) of land, and the number of HPM pilots grew by more than 200. More than 600 mulberry enterprises or cooperatives participated in HPM processing and usage (footnote 2). One of the key elements of the pilots was the provision of subsidies to farmers to shift their cropping toward HPM. Though the subsidies had some impact in the pilot counties, the expansion of areas planted with HPM has not been substantial and had no significant impact, even in areas with competing fodder crops like alfalfa, persimmon, and pasture. Areas planted with HPM are marginal in all three surveyed pilot counties (Figure 2). In Lankao County (Henan Province), more areas are planted with alfalfa than HPM; in Pu County (Shanxi Province), pasture areas are dominant; and in Fuping County (Shaanxi Province), the preferred fodder crop is persimmon.

Figure 2: Areas Planted with Hybrid Paper Mulberry and Other Fodder Crops During the Promotional Interventions of Surveyed Counties (hectares)

<table>
<thead>
<tr>
<th>County</th>
<th>HPM</th>
<th>Persimmon</th>
<th>Alfalfa</th>
<th>Pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuping County, Shaanxi Province</td>
<td>24,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pu County, Shanxi Province</td>
<td>46,667</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lankao County, Henan Province</td>
<td>4,667</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HPM = hybrid paper mulberry.

It was also observed that most areas under HPM cultivation were not planted by farmers but by the processing industry. From the three surveyed counties, 95% of the farmer respondents claimed they had never planted HPM. In Lankao and Fuping counties, only 1% of the farmers cultivated HPM in the past; while in Pu County, the number of farmers planting HPM decreased from 11% (2013) to 2% (2023). This drop in number indicates that some farmers removed their planted HPM, even though it has a life span of 15–20 years. This is quite disturbing and needs further investigation.

The nonadoption behavior holds true at the enterprise level as the areas under HPM cultivation at the county level declined. While the areas in Lankao County remained stable or decreased marginally, the decline is quite substantial in Pu and Fuping counties. This indicates that the impact of the pilots or the promotional activities has not been sustained beyond the program interventions. At the farmer level, this could be attributed to the discontinued subsidies; whereas, at the industry level, it may be caused by low profit margins or lack of appropriate incentives. Presently, there are only four enterprises processing HPM and 38 end users in the three surveyed counties (Table 1).

Regardless of the policy pronouncements that HPM is a recognized livestock feed, farmers and enterprises perceive that HPM is not a state-approved feed (Box 2).

### REASONS FOR THE POOR ADOPTION OF HYBRID PAPER MULBERRY

Several issues hinder the expansion of HPM areas, despite the fact that 79% of the farmer respondents are aware of it. Farmers’ awareness mostly comes from friends and relatives, or village cadres (Figure 3). Extension agents are not involved in the dissemination of information about HPM. The lack of a well-established extension channel in promoting HPM could be a factor contributing to the insufficient communication of its nutritional and cost-effective benefits as a feed source. As a result, none of the farmers feed their livestock with HPM, including the villages near HPM enterprises.

![Figure 3: Information Channels for Farmers’ Awareness About Hybrid Paper Mulberry](source)

Source: Asian Development Bank data from field visits in Lankao County.

It is only in Pu County that piggery enterprises are planting and using HPM as feed. At individual farms, adoption levels were low as the focus during the promotional period was on collective lands and not individual farmers. The policy pronouncements that HPM can survive in extreme environments were not realized at the farm level. For instance, Pu County has an altitude of 960 meters with a low average temperature. Local officials and farmers reported that most of the HPM trees in the demonstration park did not survive the winter season in their first year. As a result, many farmers lost interest in planting HPM. Pu County is very dry, and HPM does not grow well without proper irrigation. Under these circumstances, farmers are not willing to plant HPM, even with subsidy support.

### Box 2: Hybrid Paper Mulberry at the Enterprise Level in Lankao County

Of the three surveyed counties, Lankao County in Henan Province has the largest area planted with hybrid paper mulberry (HPM). Lankao County has one processing industry, Shenghuachun Biotechnology Co., Ltd., that uses HPM as raw material. It is a large enterprise mainly responsible for cultivating HPM seedlings, planting and harvesting HPM, and livestock breeding. It produces dried HPM powder (CNY4,000 per ton) and silage bags (CNY700 per ton), while other companies also produce HPM tea, noodles, and eggs.

Though the quality of cows and beef that are fed with HPM is good, many farmers will not plant HPM. For those who do, they cut the leaves to feed their own livestock and poultry; hence, the raw materials for HPM cannot be harvested. Shenghuachun Biotechnology expressed its unwillingness to support farmers planting HPM, since these farmers are not interested in using HPM as fodder or selling HPM in the market. The company had previously provided farmers with HPM seedlings and chicks, but later stopped.

There are chicken, cattle, pig, and sheep farms in Lankao County. HPM was once used as feed, but not anymore. This is because, although HPM is listed as a legally approved feed by the state, farmers and enterprises are not aware of this. Alfalfa and silage corn are the recognized traditional forages in the market, so farmers are more inclined to use them.

Because of the absence of information about the economic and environmental benefits of HPM, even villages near the enterprise have not planted HPM. Limited land is the main reason given by farmers for not planting HPM. Harvesting is also cumbersome, and income is uncertain. Scientific information at the enterprise level is not being disseminated to the village or farmer level.

There is also the issue of limited land. HPM cannot be planted on cultivated lands, as policies do not favor nongrain and nonagricultural crops. HPM is allowed only on hilly and degraded lands, making management more difficult. Timely harvesting is also crucial. HPM leaves should be picked at an early stage (small saplings), otherwise lignification will be advanced and HPM can no longer be used as feed. Moreover, production can only start in the second year of planting HPM; consequently, farmers favor planting corn that can be harvested seasonally.

The acceptance of HPM as a feed product is generally poor, not only among farmers but also at the market level. According to local farming companies, HPM is not suitable for feeding cattle and goats because their milk failed to meet market standards. Only one of the 38 end users from the three surveyed counties uses HPM as feed. HPM also lacks local markets because of the absence of an industrial value chain. For example, though the selling price of HPM-fed pork is high, it has a limited market. Perceptions of farmers in Fuping County echo similar views, pointing toward gaps in lab-to-land and policy-to-practice (Box 3).

**Box 3: Promoting Hybrid Paper Mulberry in Fuping County: Gaps in Lab-to-Land and Policy-to-Practice**

The current planting area of hybrid paper mulberry (HPM) in Fuping County, Shaanxi Province is less than 100 mu (6.67 hectares). At present, there is only one enterprise in Fuping County. Farmers are not willing to plant HPM, even with the support of government subsidies. Despite a strong goat dairy industry, none of the farms use HPM as feed.

Apart from low awareness and lack of demand, farmers do not consider HPM to be as good as alfalfa or corn silage as feed. Some even said that their experience of using HPM as feed for goats has not been good because the goat milk did not meet the purchasing standards.

Farmers also reported limited dialogue and cooperation with the government. Previously, the government had promoted persimmon and pepper cultivation throughout the county and promised subsidies. However, many farmers reported not receiving subsidies. Government policies also change. Once subsidies are stopped, it will be difficult to switch to other crops. This is because the flourishing root system and rapid reproduction of HPM make it difficult to switch to corn and wheat once HPM is planted.

This indicates that scientific research carried out in the laboratory could not be translated to the farmers’ fields (lab-to-land gap). As a result, awareness and promotional campaigns and policy strategies did not deliver and thus failed to meet expectations (policy-to-practice gap). This has further reduced the effectiveness of policies among farmers.

From the three surveyed counties, 485 farmer respondents were asked to identify the reasons for not planting HPM. Their responses are summarized under eight reasons (Figure 4):

(i) social influence (i.e., no one in the farmer’s neighborhood grows HPM);
(ii) economic constraints (e.g., low returns, high cost of cultivation, long wait for harvesting);
(iii) land constraints (limited land availability);
(iv) environmental constraints (i.e., HPM resilience to harsh conditions, such as extreme temperature or rainfall, lack of irrigation, poor soil quality or topography);
(v) social restrictions on growing HPM in the farmer’s location;
(vi) policy restrictions on planting trees on farmlands;
(vii) absence or lack of government support or subsidy; and
(viii) other reasons.

The social aspect is the most important reason, with 27% of respondents indicating they were discouraged to plant HPM as none of their neighboring farmers were growing it. Approximately 24% said that low returns, high cost of cultivation, and a long maturation period for harvesting were critical for their decision. However, the low returns and high cultivation cost factors are not in line with the promotional promises. About 21% of respondents indicated land constraints (i.e., limited availability of land) as the main reason for their nonadoption of HPM. Environmental constraints, together with social restrictions on growing HPM in certain locations (such as on seasonal crop lands) and policy restrictions (e.g., not allowing to grow HPM on farmlands), account for about 15% of respondents’ decisions not to plant HPM. Both social and policy restrictions go against the government’s policy pronouncements of providing a subsidy for shifting away from grain cultivation and moving toward HPM. Less than 2% of respondents mentioned lack of government support or subsidy.

**Figure 4: Reasons Given by Farmer Respondents for Not Planting Hybrid Paper Mulberry**

[Diagram showing the distribution of reasons: Social influence 26.7%, Economic constraints 23.9%, Land constraints 21.3%, Environmental constraints 5.4%, Social restrictions 4.7%, Policy restrictions 4.5%, Lack of government subsidy 1.7%, Others 11.6%]

Source: Asian Development Bank data from field surveys.
for their non-adoption decision. Other reasons cited included limited dialogue and cooperation with the government, unstable subsidy policies, limited market acceptance, and the advanced age of farmers.

THE ECONOMICS OF HYBRID PAPER MULBERRY: A BENEFIT–COST ANALYSIS

As observed from the pilot programs, cultivation of HPM can effectively increase farmers’ net incomes as a result of high yields and low cultivation costs. This, however, is contrary to the findings from the field surveys, where a significant proportion of farmer respondents pointed to low returns and high cost of cultivation as their concerns for not planting HPM. Therefore, a detailed analysis of the economics of HPM is warranted.

Pilots have shown that the average annual income of HPM growers is more than CNY3,000 per mu, which is higher than the average income for cultivating whole plant silage corn (CNY1,450 per mu per year) and alfalfa (CNY1,800 per mu per year).7 The relative economics is favorable to HPM (a perennial crop) when compared to corn (a seasonal crop) and alfalfa (a perennial crop with a life span of 5–8 years). A benefit–cost analysis between HPM and alfalfa would provide better insights.

Though it is appropriate to examine the economics of HPM using actual farm-level data, there are not enough farmers growing it among the respondents in the three surveyed counties. Hence, in the absence of farm-level data, the detailed input–output data from ADB’s policy strategy document is used (footnote 2). This input–output data is assumed to have been drawn from the pilots or demonstration parks.

Benefit–Cost Analysis of Hybrid Paper Mulberry at the Farm Level

A purely economic benefit–cost analysis was carried out using the available data on costs and returns of HPM cultivation based on the pilot planting of HPM on 70 mu (4.67 hectares) of land area. For this analysis, the following assumptions were made:

(i) life span of 15–20 years for HPM production;
(ii) production starts in the second year of planting HPM;
(iii) annual recurring costs and gross revenues from HPM remain constant over the life span;
(iv) interest rates range between 5% and 10%, which remain constant over the life span; and
(v) the minimum produce price of CNY600 per ton is used for calculating the gross revenue.

As a perennial crop, HPM has one-time costs as well as annual recurring costs. One-time investment includes seedlings, base fertilizer, and planting costs. Annual recurring costs include land lease, management and harvesting fees, and packaging costs.

A detailed cost breakdown and gross returns of HPM production are presented in Table 2. One-time investment is estimated at CNY1,449 per mu and annual recurring costs are estimated at CNY1,093 per mu. HPM plantings produce 5.535 tons per mu per year, which has a price of CNY600 per ton, amounting to CNY3,321 of gross revenue per mu per year. Yield rates go up to 10 tons per mu per year when HPM seedlings are planted on arable land, with better irrigation and other inputs. When compared to seasonal crops like corn and sweet potatoes, these returns are substantially higher.

Table 2: Costs and Returns of Hybrid Paper Mulberry Production

<table>
<thead>
<tr>
<th>Item</th>
<th>CNY/mu</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. One-Time Investment</td>
<td></td>
</tr>
<tr>
<td>Seedlings</td>
<td>1,199</td>
</tr>
<tr>
<td>Base fertilizer</td>
<td>160</td>
</tr>
<tr>
<td>Planting fee</td>
<td>90</td>
</tr>
<tr>
<td>Total (A)</td>
<td>1,449</td>
</tr>
<tr>
<td>B. Annual Recurring Costs</td>
<td></td>
</tr>
<tr>
<td>Land lease</td>
<td>150</td>
</tr>
<tr>
<td>Management and harvesting</td>
<td>500</td>
</tr>
<tr>
<td>Packaging</td>
<td>443</td>
</tr>
<tr>
<td>Total (B)</td>
<td>1,093</td>
</tr>
<tr>
<td>HPM output (tons/mu/year)</td>
<td>5.535</td>
</tr>
<tr>
<td>Price (CNY/ton)</td>
<td>600</td>
</tr>
<tr>
<td>Gross value of output (CNY/mu/year)</td>
<td>3,321</td>
</tr>
</tbody>
</table>

CNY = yuan, HPM = hybrid paper mulberry.


The farm-level benefit–cost analysis of HPM was calculated for six scenarios using two life spans (20 years and 15 years) and three interest rates (10.0%, 7.5%, and 5.0%). Cash flow measures of net present value, benefit–cost ratio, and internal rate of return were estimated. The estimates indicate that planting HPM is profitable in all scenarios (Table 3). The net present values are positive and the benefit–cost ratios are well above 2.00, clearly indicating very high net farm income from HPM production. It should be noted that this is a purely economic analysis and does not consider environmental benefits and costs. Given the close linkages with the circular economy and the positive externalities associated with low- or no-input requirements over 15–20 years, HPM has several environmental benefits. Thus, the cash flow measures are projected to be much higher when environmental impacts of HPM are considered in the benefit–cost analysis.

7 Yuan (CNY) conversion to United States dollar ($) as of 31 May 2024: CNY1 = $0.14.
Despite the very high economic returns, farmers are not expressing much interest in planting HPM. Results from the pilots or demonstration parks have not been translated to farmers’ fields, which could be because of the differences in the agro-climatic attributes or the absence of technology transfer. Often, demonstration or pilot plantations are established under controlled conditions with state-of-the-art technologies, which are often impossible to replicate in farmers’ fields (lab-to-land gap). To better understand the rationale behind farmers’ nonadoption of HPM, an assessment was made regarding the viability gap of planting HPM by canvassing with a willingness-to-accept (WTA) protocol. This would help identify whether low adoption rates are purely economic or otherwise.

**Farmers’ Willingness-to-Accept for Growing Hybrid Paper Mulberry**

For the purpose of eliciting the farmers’ WTA responses to receiving compensation from the government for planting HPM, the double-bounded dichotomous choice method was used. The specific WTA question asked was whether a farmer was willing to plant HPM, assuming that the government provided a certain amount of economic subsidies within the next 5 years. The survey provided four plans or bid alternatives (listed as A, B, C, and D in Table 4). These bids are close to the recurring costs per mu.

The farmer respondents were asked about their WTA, commencing with one randomly selected bid alternative. For example, under plan A, farmers were first asked if they would be willing to plant HPM if the government provided them with an economic subsidy of CNY300 per mu per year during the next 5 years. If they answered “Yes,” they were presented with a lower price bid—i.e., are they still willing to plant HPM if the government subsidy is CNY100 per mu per year during the next 5 years? If the respondents were not willing to accept the initial price of CNY300 per mu per year, they were given a higher price bid—i.e., CNY500 per mu per year as a subsidy. This elicitation process produced four possible responses: Yes–Yes, No–Yes, Yes–No, and No–No (Table 4).

The WTA protocol was presented to all 485 farmer respondents in the three surveyed counties by calculating the proportion of their responses to each price bid. A greater proportion (35.3%) answered “Yes–Yes” at the highest price bid (i.e., >CNY1,000). Conversely, a greater proportion (62.5%) responded “No–No” at the lowest price bid. The results of the last column indicate that the higher the economic subsidy provided, the lower the probability of farmers answering “No,” which is in line with economic theory. An open-ended question was used to elicit farmers’ WTA for switching to HPM. The results indicate that the minimum subsidy farmers are willing to accept is CNY1,269 per mu per year. Nonetheless, even at the highest price bid, only about one-third of the respondents were willing to plant HPM. This indicates that the reasons for not planting HPM are not linked to government subsidies alone, and that there could be other economic or socioeconomic considerations, as well as mandatory or coercive policies, involved.

### Table 3: Cash Flow Measures from the Benefit–Cost Analysis of Hybrid Paper Mulberry Production

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Years of Income Flow</th>
<th>Interest Rate (%)</th>
<th>Net Present Value (CNY/mu)</th>
<th>Benefit–Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>10.0</td>
<td>15,625</td>
<td>2.62</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>7.5</td>
<td>19,293</td>
<td>2.68</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>5.0</td>
<td>24,264</td>
<td>2.74</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>10.0</td>
<td>13,604</td>
<td>2.58</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>7.5</td>
<td>14,752</td>
<td>2.29</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>5.0</td>
<td>19,624</td>
<td>2.68</td>
</tr>
</tbody>
</table>

Source: Asian Development Bank calculations.

### Table 4: Farmers’ Responses to the Willingness-to-Accept Bids (%)

<table>
<thead>
<tr>
<th>Plan/Bid Alternative</th>
<th>Yes–Yes</th>
<th>Yes–No</th>
<th>No–Yes</th>
<th>No–No</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (CNY300; CNY500; CNY100)</td>
<td>12.5</td>
<td>20.8</td>
<td>4.2</td>
<td>62.5</td>
</tr>
<tr>
<td>B (CNY600; CNY800; CNY400)</td>
<td>9.8</td>
<td>24.4</td>
<td>19.5</td>
<td>46.3</td>
</tr>
<tr>
<td>C (CNY1,000; CNY1,500; CNY500)</td>
<td>6.7</td>
<td>63.3</td>
<td>16.7</td>
<td>13.3</td>
</tr>
<tr>
<td>D (CNY1,500; CNY2,000; CNY1,000)</td>
<td>35.3</td>
<td>38.2</td>
<td>20.6</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Source: Asian Development Bank calculations based on the willingness-to-accept protocol from field surveys.
When probed about the reasons for not accepting government subsidies, the noneconomic reasons become conspicuous (Figure 5). More than 22% of the respondents perceived that it is risky to shift to HPM. This perception may be due to HPM’s long life span (15–20 years). Farmers felt that once they shift to HPM, they are stuck with it for a long period and are then left with limited choices. Lack of family labor (21%) and high investment needs (19%) are the other important reasons why farmers avoid planting HPM. The investment aspect could either be a perceived or a real risk, as the cost data presented in the earlier section did not indicate such high investment requirements. As for economic reasons, less than 9% of respondents indicated that HPM is less profitable when compared to other crops and about 6% of respondents deemed that the amount of subsidy is too low. A few farmers believed that it was impossible for the government to provide subsidies, and some considered the 5-year subsidy program too short to sustain HPM planting.

Subsidies are the single largest component of the support provided to farmers for planting HPM. But, as shown in Figure 6, only about 40% of farmer respondents reported receiving direct cash subsidies (20.6%) or in-kind support (19.8%). The remaining received indirect support, such as price guarantees (20.9%), buying guarantees (18.6%), and training (18.3%). Farmers said they need direct support from the government or enterprises in the form of financial subsidies or price guarantees, along with market access for selling their HPM produce. In this regard, the end users are willing to provide price support ranging between CNY396 per ton and CNY883 per ton. The maximum support the end users are willing to pay per ton is above the minimum market price of CNY600 per ton of HPM.

CONCLUSION AND POLICY RECOMMENDATIONS

Conclusion

Our analysis suggests there is a failure in transferring research findings to farm level and in translating policy initiatives into farming practices. This is reflected in the absence of farmers’ awareness about the actual merits of HPM, primarily because of the non-involvement of technical extension staff in promotional campaigns at the village level. Some of the contradictions observed in the field affirm the lab-to-land and policy-to-practice gaps.

- HPM is promoted as an all-weather crop, but it failed in the high-altitude and low-temperature regions (e.g., Pu County).
- Subsidies are provided to farmers to replace grain crops with HPM, but farmers said they are not allowed to grow HPM on customary lands, such as farmland. HPM is allowed only on hilly and degraded lands.
- Although HPM was legally recognized as livestock feed in 2018, farmers and enterprises are still not aware of this. As a result, there is no demand for HPM products as livestock feed.
- Land constraints were not considered while promoting HPM at the farm level.
Policy Recommendations

The following policy recommendations are based on the assessment that HPM can improve farm incomes and alleviate poverty in rural areas. HPM could result in positive environmental impacts and reduce pressure on land and water resources.

- **Establish the actual merits of HPM.** Demonstration pilots on farmers’ fields should be carried out on a broader scale, covering each village or a group of nearby villages. Replication of high benefit–cost ratios (as observed in the pilots) in normal conditions at the village level would incentivize farmers and improve social acceptance, with more farmers taking up HPM.

- **Improve pilot program design.** Pilots should be broader and more diverse. They should also be replicable and scalable across different regions and agricultural contexts.

- **Foster demonstrations of economic viability.** Markets for HPM products should be strengthened by recognizing and providing the legal status of HPM as an appropriate and better livestock feed at both the household and enterprise levels. Moreover, it is essential to establish value chains from farm to industry and facilitate some value-added activities at the farm level so that farmers get additional income.

- **Adjust land-use policies to meet the needs of farmers.** A good starting point is easing or removing restrictions on planting HPM. Currently, land–use policies only allow HPM to be planted in degraded and barren land to improve soil health. It is crucial for land–use policies to carefully consider the adverse environmental implications of introducing HPM as a monoculture practice. Instead, land–use policies and planning should prioritize (i) promoting crop diversification, including food crops, commercial crops, and livestock feed crops where HPM varieties can be included; (ii) encouraging intercropping practices that integrate agriculture, forestry, and animal husbandry; and (iii) advocating for the integration of planting and breeding methods. These would enable the achievement of an ecologically sustainable industry, ensuring both cost-effectiveness and environmental friendliness.

- **Improve the consistency and duration of policies.** This would help in more effectively sustaining their impacts. As expressed by farmers, policies need to be consistent and long-term (10–20 years), rather than short- or medium-term (5 years). In the absence of policy consistency, farmers do not have sufficient dialogue and cooperation with the government, especially in terms of uncertainty in subsidy and incentive programs.

- **Ensure interdepartmental collaboration and coordination.** The agriculture department and extension services, for example, need to be given greater responsibility for the effective promotion of HPM.

- **Focus on demand-side interventions.** Up to now, HPM promotional policies and strategies have been supply-sided to the neglect of the demand-side aspects. To more effectively promote HPM, demand-side interventions should be employed, such as providing price guarantees, establishing value chains, and promoting access to markets.

- **Strengthen stakeholder engagement.** This will help generate a comprehensive view on HPM adoption. For example, it will be useful to include insights from government agencies and industry. The potential for promoting HPM as a cooperative and an enterprise farming venture could also be explored by undertaking feasibility studies.