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Encountering Plant Materiality: Limits of Large-Scale Soybean Intercropping in China

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ABSTRACT

The Chinese government has promoted maize-soybean intercropping as a strategic measure to boost domestic soybean production and strengthen food security. As a 'more-than-human' actor, soybean has historically and continues to introduce uncertainties into agrarian change. By centering plant materiality in agrarian studies, this paper examines the intercropping project in Qing County, Sichuan Province, to explore how soybeans' materiality manifests through their relations with maize, different modes of farming and diverse product markets, ultimately challenging and disrupting the policy initiative. This paper further highlights the theoretical significance of integrating plant materiality and multispecies perspectives into critical agrarian studies. By emphasizing the interconnections between plant materiality and political dynamics, it contributes to ongoing debates on flex crops and deepens critiques of the anthropocentrism embedded in agrarian capitalism.

1 | Introduction

Soybeans have played a crucial role in China's agricultural trade and food security in the last two decades. As the birthplace of soybeans, China has a history of cultivation spanning centuries. However, the country has experienced significant changes in both domestic production and international supply over time. In the first half of the twentieth century, China was the world's leading producer and exporter of soybeans and, until 1995, the soybeans it consumed were largely supplied by domestic production. Since 1996, China has been a net importer of soybeans with yearly increased imports. The domestic supply of soybeans is scarce and far from meeting the huge demand (Gale et al. 2019). Since joining the World Trade Organization in 2001, China has opened its soybean market, nearly all new consumer demand being met by imported soybeans. Soybean imports in China have increased from 20.23 million tons in 2004 to 99.41 million tons in 2023 according to the National Bureau of Statistics of China. In 2023, soybean imports accounted for 82.7% of the total soybean consumption in China[1], with 70% of these imports coming from Brazil and 24% from the United States.[2]

Soybean's fundamental role in China's food security and agricultural policy is primarily due to its biological and economic characteristics. Its high contents of protein (40%) and oil (20%) make soybean an ideal feed for livestock and therefore central to China's food security strategy, especially given the rising demand for meat. However, farmers generally do not have strong economic motivation to plant soybeans due to their lower yield and profitability (Wang 2010). As a result, the enlargement of soybean production in China must be achieved through powerful policy enforcement. After the opening of the soybean market, the Chinese government has implemented a series of policies to support the development of soybean production. In 2002, the central government introduced a subsidy policy for high-quality soybean seeds, which was later merged with comprehensive agricultural subsidies and direct grain subsidies into a farmland productivity subsidy.[3] In 2008, the central government implemented a temporary storage policy to secure the income of nonstaple crops like maize, soybean and rapeseed.[4] In 2014, the government introduced a target price policy for soybeans but failed to motivate farmers to plant more soybeans due to the low target prices and high operational costs (Cai and Gui 2024). In 2016, in addition to continuing the soybean producer subsidy, the government introduced a crop rotation subsidy policy to encourage the rotation of soybeans with other grain crops.[5] In 2017, the government adjusted its support policy to a market-based purchasing system with subsidies, which significantly increased farmers' enthusiasm for expanding soybean cultivation.[6] In 2022, the central government issued the *Opinions of the Central Committee of the Communist Party of China and the State Council in Promoting Rural Revitalization in 2022*, calling for implementing a project to enhance soybean and oilseed production.[7]

Domestic soybean production has gradually increased in recent years, from 7098 thousand ha in 2014 to 10,243 thousand ha in 2022.[8] However, the soybean self-sufficiency rate remains very low. In the context of high reliance on soybean importation and limited arable land, the Chinese government has attempted to open a new 'frontier' of domestic soybean production. The current policy for internal expansion of soybean production primarily targets two aspects. The first is to incentivize maize and soybean rotation through subsidy, particularly in the north-eastern regions of China, to restore soybean planting areas and allow the land to recuperate. Based on the resource endowments and actual production conditions of different regions, farmers are encouraged to adopt appropriate crop rotation.[9] There is only one season of grain production in the north-eastern region; therefore, it is annual or biennial rotation, i.e., planting maize for one or 2 years followed by 1 year of soybeans, or 2 years of soybeans followed by 1 year of maize.

The second target, which has broader geographical impacts, is to promote maize-soybean intercropping in the Northwest, Huang-Huai-Hai region, Southwest and the middle and lower reaches of the Yangtze River, aimed at optimizing land use and seeking to increase soybean yields without significantly affecting maize production. The technology of maize-soybean intercropping was first developed and promoted by scientists in Sichuan Province. Small-scale farmers in hilly areas of Sichuan Province had the tradition of intercropping and used to practise wheat-maize-sweet potato intercropping during the 1990s. This regional tradition, combined with growing national demand for soybeans, motivated researchers at Sichuan Agricultural University to identify maize-soybean intercropping as a critical technological breakthrough for expanding soybean cultivation in China.[10] For agricultural scientists, maize and soybeans are highly compatible for intercropping: Maize is a tall, light-demanding crop, while soybeans are shorter and shade-tolerant. Both crops share similar growing seasons and environmental requirements. Due to their similar growing requirements, maize and soybeans often compete for land, as the same plot cannot support both crops simultaneously. Intercropping maize with soybeans can solve that problem, achieve co-harvest of two crops without compromising land, fertilizer or time allocated to major grain or cash crops. The original technological rationale behind maize-soybean intercropping is to integrate traditional intercropping practices of smallholders with modern agricultural innovations, to develop suitable modern intercropping models particularly in southern China to expand soybean acreage (Zhou et al. 2010). After nearly two decades of dedicated efforts by scientists at Sichuan Agricultural University since the 2000s, maize-soybean intercropping was recognized and endorsed by central government policy and extended nationally. In 2022, the *14th Five-Year National Planting Industry Development Plan*[11] of China set forth the goal of promoting 50 million mu[12] (approximately 3.33 million ha) maize-soybean intercropping by 2025, equivalent to 25 million mu (1.67 million ha) of soybean area (Zhang et al. 2023). To encourage farmers to adopt soybean intercropping, the central government provides a subsidy of 150 yuan per mu, along with at least an additional 50 yuan per mu subsidized by the local governments. In the 17 provinces involved in the maize-soybean intercropping project, each province assigns specific soybean planting areas to municipalities, which further distributes the targets down through various administrative levels.[13]

Against such policy backdrop, this paper seeks to examine the effects of the maize-soybean intercropping project through the political ecology of crops. Critical agrarian studies have often analysed the dynamics and consequences of agrarian change 'through' the material assemblage of crops, which are typically viewed as a backdrop against which human activities and socio-ecological transformations take place. In analyses of both the means and relations of production in agriculture, human-crop/plant relationships receive far less attention compared to human-land, human-machinery and human-human interactions (Edelman and Wolford 2017). Crops are often regarded as passive, given entities that, through human labour processes, will naturally result in a harvest, serving multiple human purposes such as food, feed and industrial materials. In reality, whereas states and capitalist systems often place certain crops at the centre of growth and accumulation by defining their roles and uses (Mintz 1986; Warman 2003; Beckert 2015), crops can disrupt these efforts, reshaping the trajectory of agrarian change through their inherent materiality or 'plantiness' (Head et al. 2012, 2014). With the increasing critique on the human-centred driving forces and neglect of non-human agency in agrarian change (Taylor 2014), the integration of multispecies perspectives with agrarian studies has been reinforced in recent years to explore the role and relationships of plants in shaping the pathways of agrarian change (e.g., Tsing 2013; Wolford 2021; Fischer et al. 2022; Bray et al. 2023). In contrast to agrarian studies that typically explore grassroots dynamics through social relations (Edelman and Wolford 2017), this paper focuses on human-plant relations to examine the impacts of soybean materiality on policy implementation and its implications for agrarian change in China. This paper reveals how the materialities of soybeans manifest through their webs of relationality constituted with other crops, different farmers and product markets, ultimately disrupting the linear expectations of policy and the scale-oriented modern agriculture. By bridging agrarian studies with more-than-human geography, it aims to reveal the complex trajectories of agrarian change shaped by socio-ecological entanglements and to enrich empirical debates on human-plant relations.

2 | Methodology

2.1 | Case Study Site

Analysis of the soybean intercropping project is based on field research in Qing County of Sichuan Province in China from June to August 2024. Sichuan Province is the major province in soybean production (see Figure 1), the leading province promoting scientific research and extension on soybean intercropping and piloting soybean intercropping. Qing County has a long history of soybean plantation and intercropping. As the county annals documented, during the Jiaqing and Qianlong periods in the Qing dynasty, a wide variety of soybeans were cultivated in Qing County. One typical way was to intercrop soybeans into paddy fields without additional irrigation and fertilizer. It is for this reason that the authors conducted fieldwork in Qing County in June 2024, initially hoping to witness the revival of agricultural traditions through policy advocacy for soybean intercropping. However, decades of agrarian change in Qing County, as well as in other parts of China since the 1980s, have fundamentally altered these conditions. The widespread use of chemical fertilizers has eliminated the necessity of crop rotation for maintaining soil fertility. Soy-based foods such as tofu can be conveniently purchased at low prices from the market, and rural households do not need to plant soybeans by themselves. More importantly, the so-called 'new entities of agricultural production and operation', which include large-scale farmers, cooperatives and agribusinesses providing agricultural services, have been increasingly recognized as both pathways to and indicators of modern agriculture by Chinese governments. According to the most recent national agricultural census in 2017, there were 3.98 million large holders out of a total of 207.43 million landholders.[14] In implementing agricultural modernization projects, local governments often rely on large holders to reduce administrative costs (Gong and Zhang 2016), which exacerbates differentiation among farmers and particularly the exclusion of small-scale family farms (Yan and Chen 2015). The reciprocal and collusive relationship between local governments and large holders, with the former pursuing political achievements and the latter seeking profits, has jointly accelerated agrarian capitalism in China (Gong and Zhang 2017; Jiao and Zhou 2016).

In Qing County, grain cultivation is concentrated in the plains and orange orchards covering the hilly areas. By 2023, the area dedicated to orange orchards reached 130,000 mu, nearly matching the 140,000 mu of grain cultivation (mostly rice and maize). In plain areas, smallholders have gradually withdrawn from grain cultivation due to low returns, creating opportunities for the rise of large holders through land transfers. Large holders are the main entities in grain production. The initial policy assignment of 5000 mu of maize-soybean intercropping cultivation in 2023 was achieved through mobilizing large holders in grain production. Priority for the allocation was given to farmers with more than 30 mu. The project's goal was achieved by 29 farmers out of the 170 large holders in the county, with applied planting areas ranging from 30 to 2000 mu.

2.2 | Research Process

This research is based on interviews with large holders, smallholders, village cadres and county government officials. The maize-soybean intercropping project was implemented in the plain grain production areas across different villages. The interview with large holders was not based on villages but upon recommendation by the County Bureau of Agriculture and Rural Affairs. The authors interviewed eight large holders, including the demonstration farmer of the project and successful large holders according to the government perspective. This combination of large holders, in terms of scale, planting structure and farming experience, represents the general situation of large holders in soybean intercropping. In the plain

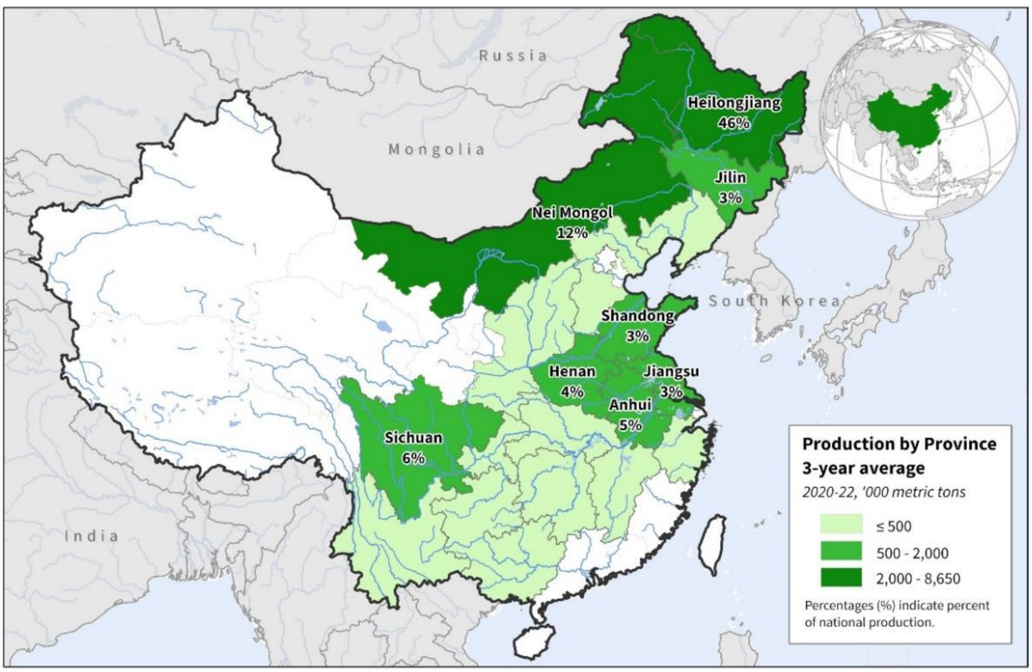

FIGURE 1 | Soybean production in China by province (2020–2022).

areas, smallholders typically kept a small piece of land for self-consumption after transferring most of their land to large holders. Smallholders who continued soybean cultivation concentrated in Qiao village, where the authors interviewed 10 smallholders (including one soy sauce artisan) to compare soybean intercropping in different modes of farming. As shown in Table 1, the rural elderly constitute the primary workforce in small-scale farming. In Qiao Village, individuals over the age of 60 account for 30% of the total population. A sharp income disparity exists among farmers operating at different scales. For elderly smallholders, annual agricultural income is typically no more than 3000 yuan. In contrast, farmers managing 30 to 40 mu of land can earn between 40,000 and 50,000 yuan per year, while those with landholdings exceeding 100 mu may reach an annual income of more than 100,000 yuan. Fewer female respondents were interviewed than male ones, as large-scale farming is predominantly managed and operated by men. Among smallholders, many elderly women were absent during the field research period because they were in the county towns assisting their adult children with caregiving. Additionally, three government officials from the County Bureau of Agriculture and Rural Affairs and the township government were interviewed to provide a comprehensive view of soybean intercropping from multiple perspectives. Following academic conventions, the names of all respondents and the places have been anonymized.

3 | Centering Plants/Crops in Agrarian Change: A Brief Review

Many crops have been deeply intertwined with the emergence of the early modern world economy and the global networks of industrial capitalism. Examples include the quick-ripening Champa rice varieties introduced into 11th-century China; the Columbian exchange; and the role of sugar, cotton, tea and rubber plantations in building colonial empires and industries for Spain, Britain, Holland and Japan (Bray et al. 2019). These are ‘global crops’ not only because they have been cultivated and circulated worldwide, but also because their histories have

TABLE 1 | Farmer respondents in the fieldwork.

No.	Respondent	Age	Sex	Identity	Crop types	Area (mu)
1	Peng Gang	41	Male	Large holder	Maize monocropping	5000
					Maize-soybean intercropping	2000
					Vegetables	50
2	Ma Hua	42	Male	Large holder; demonstration farmer in intercropping project	Rice monocropping	100
					Maize-soybean intercropping	100
					Vegetables	30
3	You Xiang	47	Male	Large holder	Rice monocropping	200
					Maize-soybean intercropping	200
					Vegetables	50
4	Cao Mei	40	Female	Large holder; village cadre	Rice monocropping	20
					Maize-soybean intercropping	200
5	Wei Xing	53	Male	Large holder; village cadre	Maize-soybean intercropping	400
6	Wang Wu	48	Male	Large holder	Maize-soybean intercropping	300
7	Zhang Yi	59	Male	Large holder	Maize-soybean intercropping	660
8	Cai Yong	50	Male	Large holder	Orange-soybean intercropping	160
9	Zheng Tian	43	Male	Smallholder; village cadre	Orange-soybean intercropping	30
10	Wang Wen	50	Male	Smallholder; village cadre	Maize-soybean intercropping	0.8
11	Li Yu	75	Female	Smallholder	Maize-soybean intercropping	1
12	Cao Wang	79	Male	Smallholder	Maize-soybean intercropping	1
13	Li Feng	72	Female	Smallholder	Maize, soybean	1.6
14	Liu Mei	75	Female	Smallholder	Maize, soybean	1
15	Li Shu	77	Male	Smallholder	Maize, soybean	1
16	Zhang Qin	60	Female	Smallholder	Maize, soybean, vegetable	1.5
17	Bao Dan	65	Female	Smallholder	Maize, soybean, vegetable	1
18	Zhang An	78	Male	Soy sauce artisan	Not engaged in farming	

profoundly linked, shaped and transformed the landscapes, populations and lifestyles of continents, regions and nations. In the face of capitalism's multiple contradictions, especially the food crisis, energy crisis and climate change, large-scale commodity crop cultivation has re-emerged as a key strategy for sustaining global capitalism (Scoones et al. 2013; De Schutter 2011; Hall 2011). Whereas historically most crops and commodities have multiple uses, the global commercial expansion of 'flex crops', typically soybean, oil palm, maize, sugarcane, cassava, coconut, etc., provoked by the current convergence of multiple crises and the need for flexible accumulation of speculators has been extraordinarily remarkable in recent years (Borras et al. 2016). The multipleness (identifying and promoting different concurrent uses of the same crop, in the form of a variety of co- and by-products) and flexibleness (the capacity of producers to switch from one use to another) of flex crops have changed the way they are produced, distributed and consumed, as well as the power relations between different agents such as landholders, agricultural producers and those who process and trade the crops (Borras and Franco 2012; Borras et al. 2016).

The political economy of flex crops examines the sociopolitical and economic contestations that shape crop flexing, with a particular focus on the roles played by the state, capital and other social actors in creating flex crop landscapes. By analysing the distribution of value and control through the question of 'Flexible for whom?', Gillon (2016) illustrated how the decision to flex US corn was influenced by agro-industrial relationships, power dynamics and the politics surrounding climate and accumulation crises. In the context of soybeans, the processing industry and agribusiness actors, referred to as 'crop flexors', have gained increasing control over the soybean complex (Oliveira and Schneider 2016). However, the diversity effect of flexing often benefits only the processing industry while leaving the productive base confined to monocultures and unification, illustrating the capitalist process of flex crops as both equalization and differentiation (Kröger 2016). In addition to market-driven forces, state intervention plays a pivotal role in crop flexing. McKay et al. (2014) demonstrated this through the example of sugarcane in Brazil, South Africa and Southeast Asia. By implementing industrial policies such as consumption mandates, tax incentives, research and development support, trade policies and credit provisions, states have facilitated the commodification of sugarcane and its integration into multifunctional industries. The development of flex crops relies on several key conditions, including a material basis, technological possibilities and profit viability (Borras et al. 2016). However, the expansion of flex crops can sometimes occur independently of material conditions due to the powerful influence of 'flex narratives' strategically crafted by corporate and state institutions (Borras et al. 2016).

While critical agrarian studies on flex crops often emphasize the political factors shaping crop flexing beyond chemical–physical and technological considerations (Borras et al. 2016), anthropologists and geographers frequently adopt a different perspective that places crops at the centre to explore their nuanced political-economic ramifications. James Scott's work highlights the intricate relationship between the material properties of rice and early state formation, contrasting it with crops like oats, barley, buckwheat, taro and yams, which functioned as 'evasive crops'. These crops' unique characteristics—such as their cultivation in difficult-to-map environments, storability, staggered ripening periods, rapid growth, ease of concealment, low labour requirements and underground growth—enabled local societies a means of resisting state domination to avoid taxes, corvée labour and military conscription (Scott 2009). In contemporary global development, political crops are defined as those crucial for national food security and political stability, with an expanded scope to reflect modern concerns (Andreoni et al. 2020). The politics of crops is shaped by their materiality and the specific historical and geographical contexts in which they are embedded. Thus, the political attribute of crops is not fixed and can shift under varying conditions influenced by different actors. For instance, under the ambiguous state propaganda surrounding flex crops, the traditional contingency crop of star anise relied upon by farmers in uncertain livelihood circumstances in Vietnam can become a source of hardship. The longer production and yield cycles of star anise transferred the risks of market fluctuations to farmers, thereby exacerbating the precariousness of their livelihoods (Turner et al. 2019). The material attributes of political crops such as cereals not only enable the state and corporations to control them but also invite resistance from farmers, and political crops thus become sites of struggle between farmers, corporations and the state (Rauchecker 2022). Drawing inspiration from James Scott, a growing number of empirical research on the political ecology of crops such as tea, onion, rubber, oil palm, Lacandonia, grass crops and illicit crops (Sturgeon 2012; Matthan 2022; Lu et al. 2022; Chao 2022; Durand and Sundberg 2022; Ó Murchú 2023) have exemplified concepts of political crops, resistance crops, speculative crops, etc., highlighting the critical role that the materiality of crops has played in shaping social, economic and political dynamics in agrarian contexts not only as means and targets of political projects.

As the diversity of crops cannot be fully captured through empirical studies, it is essential to unify research on various crops within a single overarching conceptual framework to advance scholarly debate in this field. In this sense, the concept of 'plantiness' introduced by Lesley Head and her colleagues (Head and Atchison 2012; Head et al. 2014) sheds light on research on crops/plants across different disciplines. Plantiness is the assemblage of qualities that plants have in common to differentiate them from other beings, including the following characteristics: undertaking photosynthesis; being multicellular; having predominantly cellulose walls; storing energy as starch; and having an alteration of generations in their lifecycles (sporic meiosis) (Head and Atchison 2012, 27). Recognizing that all plants are key actors possessing a degree of plantiness that predates and works independent of human control, the concept challenges anthropocentric perspectives by highlighting plants' capacities within human-plant relationships. Central to such human-plant geography is to focus on plant agency with relational approaches against the human-centred conceptualization (Head and Atchison 2012, 18). Plant agency is not viewed as autonomy isolated from human influence but as rising from plants' entanglements with their environment and their material connections to other entities where plants' material textures and interactions influence and provoke changes in human behaviour and practices (Hustak and Myers 2012). Plant agency is not a pre-existing given either but emerges through webs of relationality involving both human and non-human actors (such as the sun, water, soil, insects, animals and infrastructures) (Head and Atchison 2012, 18). Through evolving relations with smallholders, crop attributes and particular market dynamics, different plant agency could emerge, and political crops could go against the state in varying conditions as Rogers et al. (2022) showed in the case of apples and oranges in China.

Strengthening the ecological perspective and positioning crops/plants, along with other more-than-human actors, more centrally in the analysis of social transformation, has become a key emerging focus in multidisciplinary fields (Tsing 2013; Haraway 2015; Wolford 2021; Fischer et al. 2022; Bray et al. 2023). As plants play a critical role in the pressing environmental and political issues of the contemporary world including biofuels, carbon economies, food and livelihood security, human-plant geography should connect plants to a broader political framework to document the complicated and fluid relations between humans, plants and others in a new kind of 'vegetal politics' (Head et al. 2014). Given that agrarian studies have paid insufficient attention to the non-human world in understanding the dynamics of agrarian changes (Taylor 2014; Menon and Karthik 2017), the integration of multispecies perspectives with critical agrarian studies has been increasingly advocated (Fischer et al. 2022). It demands careful examination of the materiality of plants/crops, the formation of human-plant entanglements, and how these entanglements come to interact with social relations of production set within agrarian conjunctures.

4 | Soybeans as a Multifaceted More-Than-Human Actor in Agrarian Change

Historically, soybeans have functioned as a flex crop with multiple uses. Their critical role in global agrarian change primarily stems from their distinctive plant materiality. While all plants share a common plantiness such as undertaking photosynthesis, multicellularity and storing energy as starch, soybeans possess more specific and remarkable plantiness: high oil and protein contents, nitrogen-fixing ability and, in short, an exceptional capacity for energy generation. This unique energy-generating capacity has manifested itself in several ways. Firstly, they can generate energy efficiently even under unfavourable conditions. As short-day crops with relatively low soil requirements, soybeans are highly adaptable and suitable for cultivation in most areas. Their resilience to poor soil conditions, cold temperatures and drought enables them to maintain stable yields even during natural disasters (Shi 2021). Secondly, soybeans can produce more energy per unit area than major grain crops, nearly five times the protein and 30 times the fat of rice (Rahmann and Grimm 2021). Thirdly, in addition to providing energy for human consumption, soybeans contribute to ecological and agricultural systems by enriching the soil through nitrogen fixation.

Recognizing soybeans as 'more-than-human' actors, rather than merely 'non-human' entities, emphasizes their entangling relations with others, particular human actors, through which both soybeans and human societies are continuously co-constituted (Tsing 2013). As a 'more-than-human' actor in agrarian change, the energy-generating characteristics of soybean made itself an essential part of the farming system of Chinese peasants, and later the popular commodity chased by various countries for their demands in industrial capitalism. For peasants and small-scale farmers working with limited and often poor-quality means of production, soybeans have long served as a generous and reliable source of yield and nutrition. Across China and beyond, they are widely recognized as a subsistence crop. However, once incorporated into national projects of modernization and industrialization, commanded to produce maximal energy and output, soybeans reveal a far more exacting nature. They become labour- and capital-intensive, fastidious about land and machinery, and can even pose a threat to other forms of life. In short, energy-generating soybeans place reciprocal demands on humans in terms of resource input. Therefore, the performances of soybeans radically differ depending on the agrarian systems and human actors involved. Their materiality illuminates both the challenges and devastations that have unfolded in current human societies.

4.1 | Safeguarding the Poor in Peasant Agriculture

Today, much of the world's soybeans are fed to livestock, but the main importance of soy in China was initially and historically as food for humans (Da Silva and de Majo 2022). Soybean was mostly a subsistence crop or emergency crop in years of hardship in Chinese history. From the Warring States period to the Qin and Han dynasties, soybeans were planted on a large scale due to their ecological advantage. The poor people in the Yellow River basin in the Han dynasties not only used soybeans as their staple food but also as payments for rent and taxes (Guo 1993). Since the Han and Tang dynasties, beans have been gradually popularized in northern China and considered an ideal safety net crop for peasants (Shi 2021). During the Song Dynasty, the government focused on promoting beans to the vast southern region given the increased population pressure. By the Southern Song Dynasty (1127–1279), the rice-soybean rotation and replanting farming system began to be established (Guo 1993). Under the constraints of a large population and limited land resources, increasing the frequency of replanting is conducive to the full use of land and labour, and to increasing the output per unit of land area (Sheng 2008). However, the multicropping system must be based on the sustainable use of land resources. Therefore, soybeans have become the core crop of the multiharvest cropping rotation system. To this end, soybeans were often planted as a green manure crop. Farmers sometimes even did not harvest the soybeans, but instead directly buried them in the soil, which was quite common in the middle and lower reaches of the Yangtze River (Buck 2015).

Soybeans also played a crucial role in the subsistence practices of small-scale farmers outside China. In Brazil, soybean cultivation was introduced among Polish migrant communities as early as the beginning of the 20th century. Compared to corn, soybeans were of secondary importance. Since soybean farming did not yield sufficient economic returns to compensate for the labour efforts, its adoption was primarily driven by settlers' needs for self-sufficiency and for generating modest marketable surpluses. Subsistence, rather than profit maximization, was the key factor sustaining small-scale soybean production at that time (Da Silva and de Majo 2022). Even today, more than 30% of the soybean producers in Rio Grande do Sul, the birthplace of soybean cultivation in Brazil, are small-scale family farmers. While their production practices are 'modernized' and homogenized by the Green Revolution, most of the farmers kept producing soybeans as a tradition and cultural inheritance (Vander Vennet et al. 2017). A similar trajectory unfolded in Paraguay, Brazil's neighbouring country. Before soybeans boomed as an export-oriented industrial crop in the 1970s, they were primarily cultivated alongside wheat within European immigrant communities. As a winter crop, wheat requires significant nitrogen input. Cheap to sow, easy to grow and capable of fixing nitrogen, soybeans emerged as an ideal summer crop to help restore soil fertility and strengthen wheat farmers' subsistence (Hetherington 2020). In India, promoted by the state through the 'Yellow Revolution' programme in the 1980s to increase the production of oil crops, soybean was proved to be a good choice for poor farmers due to its features of low-risk, high-return and minimal input requirement, as Kumar (2016) showed in her research in Madhya Pradesh. Soybeans were resilient in both drought and waterlogged conditions. For smallholders lacking access to irrigation or the means to purchase fertilizers and pesticides, soybean cultivation still offered moderate yield. Assessed from the economic indicators, the low average productivity of soybean may suggest the failure of the state-led agricultural project. However, from peasants' point of view, soybeans have been vital to help them stay on their land.

4.2 | Becoming Demanding Along With Agricultural Industrialization

As soybeans moved from Manchuria, China to the world at the end of the 19th century, they were increasingly classified as an industrial crop for the global market rather than a subsistence crop. In the late 1920s and early 1930s, soybeans were primarily exported to Europe and Japan. The soybeans exported to Europe were mainly used in the industrial processes of making margarine, shortening, soap, canned sardines, paints and coatings and cosmetics to meet increasing demand for consumer products in industrialized societies, while exports to Japan, in the form of soybean cakes and soybeans, were primarily used as fertilizer and as raw materials for food products (Sheng 2008). During World War II, Japanese military occupation cut off the export of oil crops from Asia to Europe and the United States, which triggered the development of a new frontier for soybeans in the United States (Prodöhl 2013). The development of green revolution technologies, the institutional encouragement of the US government to advocate soybean plantation and the favourable commodity prices due to export-oriented trade policies after the war all fuelled soybean expansion in America (Mier y Terán Giménez Cacho 2016; Roth 2018). Since the 1980s, the Global South entered the scene, with Brazil and Argentina as major exporters and China as the dominant importer (Da Silva and de Majo 2022, 70; Oliveira and Schneider 2016; Langthaler 2020).

Driven by large-scale government initiatives, the growing, caring and harvesting of soybeans became more demanding, necessitating more labour, resources and infrastructure from human society. When soybeans entered America at the turn of the 20th century, they attracted little attention from farmers in the beginning, as Mattew Roth (2018) retrospect. The promotion of soybeans in the American South was not very successful for various reasons. Despite the boll weevil crisis, cotton remained the most valuable cash crop. The relatively low returns per acre of soybeans made it the last resort for small farmers. Moreover, it was believed that the soybean was more suitable for mechanized farms and incompatible with the tenancy system and manual labour work in the South. In the Midwest, soybean adoption was also slow due to its high requirements for labour and capital input. Although soybeans can grow in poor soil conditions, the high yields require a substantial fertilizer input compared to other forage crops. Farmers would have to invest more labour and capital to get sufficient value out of soybeans, which further limited their expansion (Roth 2018).

In the early history of soybean cultivation in the United States, the most serious challenge posed by the soybean was its harvesting, which had long constituted a bottleneck. About 1910, farmers cut soybeans with a cane knife and beat them over a sheet of woven wire stretched across a wagon bed. Later, many growers in the South used mule-drawn row harvesters that beat the beans off the standing stalks into a box (Strand 1948). To grow and harvest soybeans requires much more man-hours, horse-hours and tractor-hours than other crops in the 1920s. Furthermore, soybean's quality of shattering—soybean pods dehisce after maturity—aggravated the difficulty of harvesting. Thus, many harvesters refused to handle the beans because they were 'more skeptical than the cow' (Dies 1942, 36). In the 1930s, when harvesting could be done with a binder, threshermen finally accepted soybeans as a necessary evil (Dies 1942, 35). It was not until the introduction and extension of combine in the 1940s that large-scale soybean cultivation was further expanded and mechanized (Strand 1948).

Despite the improvement of machinery over the decades, the challenge posed by soybeans in mechanical harvesting remains. In the United States, soybean harvest losses represent approximately 2% to 4% of total potential yield under good harvest conditions (Staton 2023). A similar plight exists in Brazil as well—the average 4% harvest loss accounted for the highest proportion of soybean loss, the larger the farming scale the bigger the harvest loss (Arends-Kuenning et al. 2022). The agricultural engineering imperative to reduce harvest loss across major soybean-producing countries further demands intensified inputs and increasingly rigid mechanical and technical operations. In the United States, for example, soybean production has become more input-intensive over time. While the total cost per acre of soybean increased 100% from 2002 to 2018, the yield increase was far below that pace (Vaiknoras and Hubbs 2023).

Perhaps the demanding feature of soybeans under industrial agriculture finds its most extreme expression in South America, where soybean production has increasingly become synonymous with large-scale capitalist agriculture (Vander Vennet et al. 2017). As soybean monoculture expanded, it required simplifying the landscape and reducing all kinds of obstructions, materially and institutionally, on the horizontal space (Hetherington 2020). Land grabbing and rising pesticide applications to accommodate soybean monocropping have triggered a range of ecological and social devastations as mountains of literature have documented (Oliveira and Hecht 2016; Porro 2005; Sawyer 2008; Gordillo 2014). All of this made soybean a complicated social, political and environmental actor that Paraguayan peasants and rural activists even yelled 'soy kills' or the 'killer soy' to express their anger and grief over the loss of life in all its forms: land dispossession, sickness, deforestation, climate change, forced labour migration, biological manipulation, violence, poverty, injustice, etc. (Hetherington 2020). Beyond the political-economic critiques of flex crops and soybean expansion, it is essential to reconsider the scenario through the lens of plant materiality. Without acknowledging the materiality of soybeans, we cannot understand how a safeguarding crop can become a killing crop in different socio-ecological contexts. The more value human actors seek to extract from soybeans, the more significantly their plant materiality shapes agrarian change, as we have seen from above.

5 | Soybeans' Material Dynamics in the Intercropping Project

The soybean intercropping project in China, extended as both a technological invention and political mandate, becomes a frontier for the state's soybean production as well as a new contact zone between plant materiality and human intervention. This project is unique as it tries to maximize land use in large-scale industrial agriculture by borrowing the traditional way of intercropping in small-scale farming. The complex purpose of the project placed soybeans in an awkward situation; therefore, the soybeans complicated the project as a demanding and disturbing actor. The significance of soybeans' materiality in the maize-soybean intercropping project is not considered by either farmers or government officials in the beginning but gradually emerges through its entanglements with human and non-human actors: different crops, different farmers and their farming styles, as well as different markets for soybeans of different forms. Through relations with those factors, soybeans' plant materiality became salient, which ultimately challenged the state's agricultural initiatives in soybean expansion, introducing greater uncertainty into the future trajectory of agrarian change in China.

5.1 | Conflicting With Maize

Intercropping is a spatial arrangement in farming that integrates crops with differing heights and characteristics to optimize yields and profits. As such, the relationships between crops are central to the success of an intercropping system. In Qing County, soybeans, with their shorter nature, are often positioned beneath taller plant companions, not only maize but also orange trees and bamboo. In sparsely planted or newly established orchards, soybeans find room to thrive, covering up to 80% of the ground during the first year. While orange trees do not bear in the first 2 years, soybeans could offer some interim value to farmers, once again demonstrating their safeguarding quality. However, such plant combination is fleeting. By the third year, orange trees and bamboo would grow densely, casting significant shade and making the environment unsuitable for soybeans. With trees gradually maturing, the supplementary soybeans would quit.

A more conflicted relationship unfolds in the government-promoted maize-soybean intercropping system. Technically, various row arrangements in maize-soybean intercropping are promoted by governments and research institutes, ranging from 2M3S,[15] 2M4S, 2M6S, 4M3S, 4M4S and others, depending on the light, heat, soil and water resources of different regions. In Sichuan Province and other southwestern regions, 2M3S and 2M4S are the most common patterns. In practice, farmers in Qing County could shift between different row arrangements based on market conditions: They opt for 2M6S to grow more soybeans if soybean prices are higher or switch to 2M3S to focus on maize if maize prices rise. Large holders typically adopt the 2M3S arrangement to maximize corn yields (Figure 2).

While the cohabitation possibilities of maize and soybean offer farmers a range of cultivation choices in different contexts, their coexistence should never be taken for granted. The agronomic synergy of intercropping cereal crops with legumes is far from natural if the relational dynamics of crops are considered, especially under large-scale industrial agriculture. The first conflict between maize and soybean lies in weed control. Maize and soybeans are chemically incompatible. Herbicides effective for maize are often harmful for soybeans, and vice versa, as they belong to different plant families. Such incompatibility limits farmers' choice; they must choose herbicides that are safe for both crops, but there is no such product on the market. In practice, maize takes precedence—large holders usually plant maize first, apply herbicides for sprouted maize over the entire field, and then plant soybeans to minimize the impact of differing herbicides. However, conflict still exists; it becomes more difficult to control subsequent weeds for both crops after the initial closed weeding.

The chemical incompatibility of maize and soybean is also reflected in fertilizer application. The two crops have distinct nutritional requirements—maize typically needs compound fertilizers and urea, while soybeans require high phosphorus and potassium; maize demands sufficient nitrogen fertilizer, and soybeans need less nitrogen fertilizer. The ecological contribution of soybeans in nitrogen fixation is gradual and insufficient to meet the accelerated yield expectations of industrial agriculture. As a result, farmers could not reduce the input of nitrogen fertilizer at the risk of lowering yields. Moreover, once chemical fertilizers were integrated into the farming system, it became increasingly difficult to maintain soil fertility solely through green manure crops.

The most acute friction between the companions lies in harvest. When planted separately, both maize and soybeans are well-suited to industrial monocropping and easy to plant and harvest with machinery. However, mechanical harvesting reveals its fatal limit in intercropping systems. It struggles to deal with complex, real-world ecological systems, even when involving just two crops. Synchronism is the central prerequisite for industrial agriculture: one single crop needs to be sowed, managed and harvested on a large scale at the same time with machines designed for singular purposes. Nonetheless, maize and soybeans do not mature simultaneously, and harvesting one crop will inevitably hurt the other. Furthermore, they require different machines—a narrow crawler harvester for soybeans and a high-clearance straddle harvester for maize. Harvesting both crops at the same time would demand the use of both machines simultaneously, which is hardly possible due to operational complexity.

FIGURE 2 | Maize-soybean intercropping in the field.

Large holders do not have suitable machinery for simultaneous harvesting as well. To minimize machinery investment costs, none of the interviewed large holders have harvesters. They have smaller machines like rotary tillers and rice transplanters while renting drones and harvesters from agribusinesses to handle larger tasks.

In maize-dominated intercropping systems, large holders typically harvest maize first, which inevitably damages the soybean plants. Yet, soybeans are no less powerful than maize as they pose greater demands and trouble during harvest. Since the soybeans are harvested fresh, they demand gentle hand work (as explained in Section 5.3). Their biological specificity interrupts the mechanized logic of grain extraction so that large holders could only resort to manual labour if they want to get rewards from soybeans. The gains come at a high price. The labour cost for harvesting soybeans is approximately 1.4 yuan/kg. With an average yield of 400 kg/mu, the harvesting cost per mu reaches 560 yuan—more than four times the cost of harvesting maize. Given all the challenges, large holders are unlikely to adopt soybean intercropping without subsidy stimulation.

> I've been planting maize for years. For large-scale maize plantations, mechanical harvesting is very efficient. The cost of mechanical harvesting is 130 yuan per mu. The problem is that the subsidy for maize is only 90 yuan per mu, and it was even lower before. So, the 300 yuan per mu subsidy for maize-soybean intercropping is significant. Even so, I don't want to intercrop because it's much more troublesome compared to maize monocropping.

(Fieldwork notes on 2 August 2024, large holder Peng Gang)

The purpose of subsidies is to motivate farmers by offsetting the costs of cultivating less profitable crops. However, the intercropping subsidy fails to achieve this goal due to the material conflicts of crops. Thus, soybeans become a quintessential political crop for large landholders—a crop that embodies state will and intervention, with its cultivation heavily dependent on political incentives. In contrast to the win-win narrative promoted by government propaganda about maize-soybean intercropping, 'maintaining the same maize yield while gaining an additional soybean harvest',[16] the plant materiality of both maize and soybean and their relational dynamics, presents significant challenges for large-scale industrial agriculture in practice. The conflicts between the two crops reflect a deeper tension between state directives and the drive for industrial simplification on one hand and the unruly demands of the crops on the other.

5.2 | A Bias Against the 'Big'

In the plain areas in Qing County, there are two farming seasons. In the first season of the so-called 'big spring' (大春), local people grow grain crops such as rice, maize and sweet potatoes in the spring and harvest in the autumn. In the second season of the 'small spring' (小春), they grow wheat, vegetables, oil crops and other cash crops in the autumn and harvest in the next spring. Soybeans are integrated within such a continuous and overlapping cycle, but their entanglement with farmers varies in different farming styles. They empower some with self-sufficiency and resilient livelihoods, while burdening others with interruptions, depending on how farmers could align with their rhythm.

Some small-scale farmers adopt maize-soybean intercropping although their areas are unqualified for government subsidies. For them, planting soybeans is a livelihood strategy rather than a response to policy incentives. Villages in Qing County, like many rural areas in mid-western China, have experienced a trend of rural labour migration since the 1980s. As adult children migrate to urban areas for nonfarming jobs, villagers above 50 and 60 become the primary residents and labour force. After land transfer, many elderly smallholders adopt a similar pluriactivity and farming arrangement—they grow maize, soybean and vegetables for self-consumption and petty commodity production and work as wage labourers on the land transferred to large holders. Soybean and maize form a complementary combination for smallholders: Maize offers higher yields for feed, while soybeans provide higher profit for cash. This farming structure helps stabilize income, especially for the elderly.

Compared to the entrepreneurial mode of farming and the capitalist mode of production, the peasant mode of farming typically emphasizes the centrality of labour. With a limited resource base, it is the quantity and quality of labour invested by peasants and smallholders that drive value-added production and intensification (Van der Ploeg 2008). The labour input by smallholders is critical to coordinating the conflicts between maize and soybean. To reduce the chemical incompatibility between the two crops, smallholders would do hand-weeding or use covers to protect one of them when applying herbicides to the other. As a demanding crop in the intercropping system, soybeans are always reciprocal and generous to farmers who are willing to input care and efforts. Plant vitality and human efforts reinforce each other, as farmers observed, 'the better the beans grow, the easier they are to pick'. In return for their attentive labour, soybeans offer temporal flexibility and a reliable income for smallholders. Their growing period, from 70 to 90 days, allows most smallholders to stretch production across a prolonged double season from February to September (see Table 2), some are even able to harvest three seasons a year.

> We only have 0.8 mu land, and we plant maize and soybeans on it. Although the planting area is too small to get any subsidy, we would plant them anyway. Smallholders are better at intercropping than large farmers because we do farm work with more care. We pay more attention to soybeans and plant soybeans first. We plant maize only when the soybeans come to maturity to reduce their conflicts. Every year, our net income is 2,000 yuan from spring soybeans, 1,000 yuan from corn, 1,000 yuan from summer soybeans, and another 1,000 yuan from vegetables. It is an important source of income for the elderly in the village. If managed well, we can keep the beans as seeds for several seasons.

(Fieldwork notes on 30 July 2024, smallholder Wang Wen)

Specific plant materiality requires specific schedule and coordination of labour process. In this sense, the distinctive temporalities of plants could pose a significant challenge to the structures of the industrial capitalist regime (Lawrence 2022). In contrast to its empowerment to smallholders, soybeans stand as biopolitical mandates for large holders whose central concern is to shorten the growing period of soybeans and reduce their interruptions in the field. After harvesting grain crops in the 'big spring', profitable cash crops in the fall are the real battlefield to make more profits. Some large holders even subtransferred the use right of their transferred land in the first season to other farmers to reduce costs and concentrate on the following crops.

> Due to market fluctuation and climate change, it's increasingly difficult to choose fall crops. Fall crops generally face a trend of reduced production and difficult marketing. Additionally, land rental fees in recent years have been increasing; the current rent is 1,100 yuan per mu per year, while some villages reach

TABLE 2 | Typical farming schedules of smallholders and large holders.

	Months												
Type	**Crops**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**
SH	Soybean	■		□		■			□				
	Maize		■		□								
	Vegetable								■			□	
LH1	Maize	■				□	■			□			
	Soybean		■			□							
LH2	Maize	■			□		■			□			
	Soybean						■			□			
	Vegetable									■			□
LH3	Maize	■				□							
	Soybean		■			□							
	Rice					■			□				
	Vegetable									■			□

Abbreviations: □ = harvest, ■ = sow LH = large holder SH = smallholder.

> 1,400 yuan. The profit space in agriculture is being squeezed so that the fall season is like gambling for us.
>
> (Fieldwork notes 13 August 2024, large holder Cao Mei)

In this context, unlike the 'gentle farming' practiced by smallholders in soybean intercropping, large holders adopt a 'fast farming' strategy. They structure their farming schedules to align with market speculation instead of the temporality of soybeans, rapidly exploiting available ecological resources for maximum profits. As Table 2 shows, the farming calendars of large holders are usually made from maize. Soybeans are incorporated into their schedules only for one season typically in three ways: inserted into maize monocropping (as in LH1), inserted into a maize-vegetable rotation (as in LH2) or integrated into a rice-vegetable rotation (as in LH3). Theoretically, large holders could plant soybeans as monocrops after harvesting maize to avoid the competition between crops in intercropping systems. In practice, however, this is not a rational choice. One reason is that soybean monocropping is not subsidized in Sichuan Province. More importantly, large holders generally favour maize monocropping because it is more profitable. It is more challenging for large holders to get similar profit from mechanized soybeans monocropping due to their unique plantiness (as shown in Section 5.3). Therefore, once the land is freed after the soybean harvest, it would be quickly reactivated for growing other crops to make full use of the working time of the land.

> We must pay over 200,000 yuan in land rent every year to the village, so whether it's spring or autumn, we can't afford to leave the land idle. Now we must plant three seasons a year, and after completing the task of maize-soybean intercropping, we must quickly switch to vegetables, which can be sold during the 'golden' period before the New Year.
>
> (Fieldwork notes 4 August 2024, large holder You Xiang)

As a result of such compression, soybeans, rather than offering the temporal flexibility they afford to smallholders, sound a relentless alarm of urgency to large holders. Soybeans' strict demand for immediacy, particularly during harvest, will translate to a significant loss for industrial agriculture as explained above. For the harvesting of normal dry beans, if harvested too early, the high moisture content of soybean overwhelms the harvester; if harvested too late, soybeans will shatter upon touch. Kumar (2016) rightly summarized the large-scale soybean harvesting in India as an 'economy of haste'. In Qing County, the harvesting of fresh soybeans is even harder. Soybeans' tender pods and short harvest windows require prompt harvesting by a large number of manual labourers. Based on large holders' calculations, harvesting 1 mu of soybeans requires an average of four manual labourers every day. In other words, a large holder with 100 mu of maize-soybeans intercropping will need about 60 labourers every day. Poor-quality soybeans due to extensive management would exacerbate the difficulty in harvesting.

To cope with the immediacy requirement, large holders mobilize not only elderly wage labour through local brokers but also prompt labour searches beyond village borders. To compete for labour, some large holders even temporarily raised wages from 20 to 24 yuan/kg and further intensified the competition. Given the short duration of the soybean intercropping project in Qing County, the extent to which soybeans will reconfigure the labour relations remains uncertain. However, soybeans have already proven their powerful role as non-human actors in reshaping labour relations in other cases. In Kumar's (2016) study in central India, soybeans have made unprecedented space for Adivasi labourers from lower castes to negotiate wages and conditions with upper-caste landowners during harvest. We can anticipate two possibilities in Qing County if the policy continues: increased mechanization and capitalization to alleviate labour shortages, or the emergence of a more nuanced rural labour market shaped by the temporal and material demands of soybean. With no doubt, either pathway will place large holders at further disposal of the crop.

5.3 | The Dominance of Tenderness

Different from the multiple uses of soybean as a 'flex crop' in modern manufacturing, in Qing County, soybeans are harvested fresh as vegetables, a niche high-value product. Soybeans are consumed as fresh vegetables rather than in processed forms. In the flex crop discussions, the versatility of crops is usually related to their by-products that can easily be developed into important commodities in a changed context. For soybeans, in the context of the global political economy of livestock, the main product is soymeal, with soy oil being the by-product that can be directed towards food uses or transformed into biodiesel (Borras et al. 2016). The case in Qing County revealed another plantiness of soybeans that shapes agrarian scenarios: its morphological versatility and tenderness.

As a nutrient-dense crop rich in protein, soluble sugars, starch, dietary fibre, minerals, isoflavones and vitamins, vegetable soybeans have gained global popularity as a vital component of sustainable diets (Rosso et al. 2024). In recent years, awareness of the health and nutritional benefits of vegetable soybeans has led to growing demand from both domestic and international markets. Currently, China, Japan and Taiwan are the leading producers, while major consumer markets include China, Japan, Korea, the United States, Taiwan, Thailand and Europe (Nair et al. 2023). China is the leading producer of vegetable soybeans, with 90% of the total area and production (Zhang et al. 2017). The rising market for vegetable soybeans has a strong influence on farmers' choices. A segmented soybean market exists in Qing County, where a large quantity of fresh beans is demanded and procured by middlemen and companies for distribution to domestic metropolises like Beijing and Shanghai, and dried beans are typically sold locally in smaller amounts for tofu and soymilk production. Price is the primary concern in farmers' decision-making. The yield of monocropping fresh soybeans per mu is around 800–900 kg, with a farm gate price of over 4 yuan/kg, while the same area yields only 100–150 kg of dried soybeans, sold at 7 yuan/kg. The temporality of the multiple cropping system is another reason that farmers prefer fresh soybeans. Fresh soybeans take about 75 days to grow, while dried soybeans require at least 100 days. The shorter growing period of fresh soybeans allows farmers to harvest earlier and prepare their land for the next planting cycle.

The tenderness of soybeans makes them a new profit focus. However, their plant materiality again plays a central role in shaping fresh beans production practices. The delicate pods of immature soybeans are easily bruised or crushed by even moderate mechanical force. As early as 1942, Dies already noted the special attention demanded by fresh beans. For use as a green vegetable, the pods should be picked before the soybeans have reached full size and before there is any tendency to turn yellow. When they are too ripe, the beans have lost much of their tenderness (Dies 1942, 87). Due to the highly perishable nature of the pods, the harvesting window is extremely narrow, leaving farmers only a few days to harvest and sell them before they turn yellow (Nolen et al. 2016). Modern agro-economic research has further quantified the considerable cost in exchange for the tenderness. Labour costs make up approximately 62% of total production expenses of fresh beans, with the majority allocated to manual harvesting (Garber and Neill 2019). While mechanical harvesting can reduce production costs by about 28%, it also leads to yield losses of up to 24% compared to hand harvesting (Born 2006).

Farmers in Qing County just face the same challenge. Harvesting fresh beans requires both gentleness and immediacy. Fresh beans must be harvested within a narrow 5-day window; otherwise, the beans get matured and hard. For smallholders, particularly the elderly, the act of picking beans is carried out with care and patience, unburdened by the calculus of labour cost. Their intimate farming rhythms align well with a crop that demands gentleness. In contrast, manual harvesting of fresh beans is extremely challenging for large-scale intercropping; in some cases, soybeans could not be harvested at all.

> I've planted 3,000 mu of maize, and 2,000 mu of maize-soybean intercropping. Large holders like me generally don't harvest the soybeans in the intercropped fields; they're just left to rot in the ground. With maize-soybean intercropping, you must choose—either harvest the soybeans or the maize. Smaller-scale farmers with just a few dozen mu or 100 mu can manage to harvest both with manual labor, but on larger scales, it's not possible.
>
> (Fieldwork notes on 31 July 2024, large holder Peng Gang)

Despite the many challenges in field management and harvest, driven by the higher price, most large holders still attempt to harvest fresh soybeans. As a result, the expanded soybean acreage under government promotion has not translated into an increased supply of fodder or oil. This divergence reveals a fundamental discrepancy in the project's implementation. Such discrepancy has not gone unnoticed by the local government. The County Bureau of Agriculture and Rural Affairs oversees the whole process of project implementation from selecting large holders, documenting their planting areas, to monitoring and evaluation. Upon receiving large holders' harvesting applications, the county bureau went to the field to measure the acreage, assess crop quality and complete data collection. Subsidies are paid to large holders afterward if the planting area requirements are met, regardless of the forms or the end use of the soybeans.

> Planting area is the most important concern. This is because our superiors just focused on area requirements, and the policy didn't indicate the usage or the forms of soybeans. The government's policy is well-intentioned, but there are still problems in implementation. This is a systemic problem, not a problem with our local government. Many people are unwilling to farm even with subsidies. Everyone is calculating profits—if farmers' economic benefits are not guaranteed, then the implementation of these policies cannot even be considered. We can foresee that the maize-soybean intercropping project will face difficulties in the future.
>
> (Fieldwork notes on 14 July 2024, official in County Bureau of Agriculture and Rural Affairs, Zhang Xu)

For government officials working within the hierarchy, it is the planting areas, or the figures, that determine the success or failure of the project and are crucial to their political performance evaluation and career development. Therefore, maintaining close relationships with large holders and providing them with sufficient incentives is essential for local governments to fulfill the growing intercropping tasks. Peng Gang was the only targeted large holder whose subsidies were reduced due to poor soybean quality. As compensation, he received an additional task of 1000 mu from the county bureau in a project to reclaim forest land for farming, which is fully subsidized regardless of crop yields or quality. Such governance logic at grassroots levels distorted the original intentions of the policy, yet it just exposes the complex reality vis a vis the state simplification in agricultural governance (Scott 1995). This is especially evident when the intricate entanglement of farmers and plants is considered. While discontinuity in policy implementation is common in rural politics, in this case, it is the plant materiality becoming the critical factor in deconstructing the state project. Like human actors, soybeans are not static objects in the field but living entities with organic life. Their evolving relationships with other crops, farmers, consumers, government officials and markets continuously shape and reshape agricultural dynamics, generating conflicts and creating spaces of manoeuvre for human actors. Soybeans' materiality helps to safeguard the poor and reward those who care, whilst disturb and unsettle other attempts of appropriation. These shifting performances are not contradictory; rather, they illustrate plant materiality as a dynamic variable in shaping agrarian change through its evolving entanglements with diverse actors.

6 | Conclusion

In the context of heavy reliance on soybean imports and limited arable land, the Chinese government has been promoting maize-soybean intercropping in recent years to expand domestic soybean production. While agronomists and the central government advocate maize-soybean intercropping as a technical 'fix' to optimize resource use and address food security, soybeans' materiality and the human-plant relations have not been fully considered in the scenario. The intercropping project has seen success from a nationwide increase in soybean sown area—reaching 20.16 million mu in 2023, an increase of 5 million mu from 2022.[17] However, these macro-level narratives and statistics become questionable when examined from the grassroots level, particularly through the lens of plant materiality. The material conflicts between maize and soybeans defied the assumed synergy of intercropping by agricultural scientists and demythologized the efficiency of agricultural mechanization. By imposing their own temporal and labour demands, soybeans frustrated large-scale farming and sowed the seed for agrarian differentiation in the future. The polymorphic body and tenderness of soybeans have opened new markets and directed farmers' practice, ultimately enabling their evasive use in ways that diverge from the original policy intention. The materiality of soybeans, through its entanglement with different human and non-human actors, has shaped farming arrangements, influenced labour processes and introduced uncertainty into soybean expansion policies in China.

Given the short period of the project implementation and the small area of soybean cultivation in Qing County, this case alone is not sufficient to question the overall outcome of the maize-soybean intercropping project in China. However, the situation in Qing County is not unique; another ongoing research in Hebei Province by one of the co-authors reveals similar discontinuities. These grassroots cases call into question the rationality of agricultural policy that overlooks the complexity of plant materiality in agrarian change. Although the promoted intercropping technology drew inspiration from the traditional practices of small-scale farmers in the hilly areas of the southwest, both scientists and the central government underestimated its incompatibility and practical challenges for large-scale farmers, who are in fact the backbone of grain production across China. The policy not only fails to offer sufficient incentives for large holders to intercrop soybeans but also increases the mechanical and financial pressures they face in addressing the challenges posed by plant materiality and in meeting the policy targets. Therefore, beneath the growing figures of soybean production, there might be numerous trivial stories and unintended deviations shaped by the plant materiality of soybeans and other plants. This paper does not seek to evaluate the entire intercropping project but aims to deepen our understanding of agrarian change by drawing insights from plant materiality and multispecies perspectives. This paper suggests three theoretical implications of integrating plant materiality into agrarian studies.

Firstly, plant materiality enriches debates on the political economy of flex crops by emphasizing the continuous interplay between plant materiality and political dynamics. In critical agrarian studies, discussions on flex crops often focus on the social, economic and political contestations that shape crop 'flexing'. However, beyond those forces, the materiality of crops themselves remains a fundamental factor. The boom of flex crops over the past decades is driven, on one hand, by the materiality of crops themselves. On the other hand, these very traits make the process of crop flexing an ongoing and contested battlefield. The niche market of vegetable soybeans, as this paper shows, though smaller than grain soybeans, further intensifies the competition over soybeans' flexibility. New markets and stakeholders would rise and join the arena when new characteristics of crops are discovered and valued. New forms of plant agencies will emerge consequently, introducing fresh dynamics and uncertainties into human-plant relations and shaping the trajectories of agrarian change. The interplay between plant materiality and the political economy of flex crops highlights the diverse possibilities of 'flexing', which needs closer attention to the material basis of crops to better grasp the dynamics of agrarian change at various levels.

Secondly, plant materiality introduces new dynamics into grassroot trajectories of agrarian change by highlighting the crucial role of crops as 'more-than-human' actors. In many analyses within the political economy of flex crops, crops are often regarded as their end products rather than as living entities that actively shape political and economic processes. However, plant materiality is embedded in farming practices as a significant ecological variable that interacts with specific people in specific agrarian systems. Through the co-production of humans and nature, plant materiality can be translated into human agency that enables human actors to exercise certain degrees of autonomy in pursuing their purpose. As this paper illustrates, the tenderness of immature soybeans impedes the wheels of mechanization and intensified competition for wage labour. In contrast to the disruptive effects of soybeans on large holders, smallholders were more able to benefit from the energy-generating soybeans and enhance their livelihood. Beneath the overarching trend of large-scale industrial agriculture in China, the subtle variations and unpredictable differentiations introduced by plant materiality deserve closer attention. Incorporating plant materiality into agrarian studies thus helps redirect attention to the struggles and interactions unfolding in the field, offering a more comprehensive understanding of agrarian change and revealing socio-ecological dynamics that often remain overlooked.

Finally, plant materiality provides a critical tool for challenging the human/nature binary in agrarian capitalism. The distinction between nature and society is capitalism's organizing principle (Patel and Moore 2017). The construction and separation of nature as a distinct entity facilitate capital's processes of appropriation and accumulation. Historically, the expansion of commodity frontiers in pursuit of cheap crops has relied on spatial fixes (Harvey 1981) and technological fixes (Clark and York 2008). The growth of soybean production has consistently been driven by the domination and exploitation of nature, whether in early 20th-century China or Brazil since the 1970s (Oliveira and Schneider 2016; Langthaler 2020). In this process, large-scale industrial agriculture has been gradually framed by neoliberalism and various governments as the most efficient solution for food production. However, as this paper demonstrates, large-scale industrial agriculture reveals critical flaws in adapting to intercropping and biodiverse farming systems, as it fundamentally depends on the simplification of nature and the objectification of crops. Despite (bio)technological advancements in industrial agriculture, crops remain inherently dependent on the essential nutrients provided by nature, just as humans are entirely reliant on plants for survival. This interdependence explains the persistent human efforts and struggles surrounding soybean production on both domestic and global scales. The frontier-making of commodity crops would inevitably encounter ecological limits. Without transcending anthropocentrism and recognizing plants—as well as other species—as active subjects in agricultural systems, technical solutions for soybean production, such as land consolidation, mechanization or transgenic breeding, will fail to address the core issue of sustainability. Acknowledging the intricate entanglements between humans and plants not only deepens critiques of agrarian capitalism but also opens alternative pathways for agrarian change.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

Endnotes

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