

Supplementary Materials

Maize

Thailand

In Thailand, an expansion of the maize area took place from 1960 until around 1990. The introduction of maize was a deliberate state policy to diversify production from rice and rubber. In this period, Thailand was a net maize exporting country. Meanwhile, yields fluctuated but did not improve systematically until 1980.

Following a peak in the mid-1980s, the maize area has contracted, but production has remained high due to substantial yield improvements from 1980. The high production can be related to increasing domestic meat consumption and exports of in particular poultry [96,110], with government price stabilization programs on selected broiler feedstuffs [114]. The increasing gap between cultivated area and yields since the mid-1980s reflects an intensification which is partly brought about by various governmental programs e.g., subsidizing hybrid seeds. The national statistics disguise a trend of contracting lowland maize area and a rapid upland expansion after 2001 [122].

The post-2000 upland maize expansion is partly driven by a tripling of the domestic maize price in 2005–2011, and by micro-credit programs making it possible for small scale farmers to engage in annual crops that rely on external inputs [75, 124]. However, during the same period the different Thai governments also increasingly enforced a ban on swidden agriculture, which pushed farmers and towards continuous cultivation systems [75,112].

Vietnam

Until 1975, Vietnam's maize area was at a steady but low level. In the late 1970s, the area expanded by 100% almost doubled and remained constant until the early 1990s. Curiously, maize yields do not follow the sudden areal expansion, but increased slowly until the early 1990s. Since then, feed demands from the livestock and poultry industry have driven a 300% expansion and 400% yield increase, with intensification aided by government introduced hybrid maize technologies and promoted through research and extension services, as well as technical and financial support from international organizations [111]. The HYV seeds were quickly adopted by the farmers. Since the majority of the maize is produced in the uplands, improvement of market access and commercialization also had a large impact on the increased production.

Cambodia

The maize area exhibited a cyclical but steady contraction from 1960 to the late 1990s, along with a yield decline until 1988. Since 1997, the maize area has expanded by roughly 500% while yields have increased more than 500%, reflecting rapid expansion and in particular intensification. The onset of these trends coincides with the country's transition from a planned economy to a market economy with the majority of the production being exported to neighboring Vietnam and Thailand [117].

Both maize and cassava often serve as intercrops in immature rubber plantations, and the expansion of rubber thus has a spillover effect on the maize and cassava areas [120].

Laos

The maize area in Laos has been almost neglectable until the early 2000s. Since then, the area has expanded 5-fold. Yields were declining from 1960 to the mid 1980s, and have increased more than 500% since then. Production increases from the mid 1980s to 2000 can thus mainly be explained by intensification, and since the early 2000s by expansion and intensification working in tandem. Most of the maize production in Laos takes place under contract-farming agreements [100]. The expansion of maize cultivation in Laos has mainly been driven by demands from the markets in Vietnam and Thailand and facilitated by increased accessibility due to road development and introduction of

hybrids [100,105,107]. The development of contract-farming schemes has been supported by the Lao government that has a strong policy vision about ‘turning land into capital’ [68,100]. The development has also been pushed by land policies aiming at eradicating swidden agriculture by allocating limited areas for intensive commercial agricultural production —especially of maize—which have incentivized farmers to intensify production in upland areas [107].

Cassava

Thailand

From 1965 to 1989, the cassava area of Thailand boomed, with a 1,600% expansion, whereas yields largely remained stagnant. This was due to expansion into less suited areas, with associated low or declining yields [108], balancing out any yield increments in intensively cultivated areas.

This was followed by a +60% contraction and only modest yield increases from the late 1980s to roughly 2000, resulting in a +50% production decline. The expansion of the cassava area in the 1970s was driven by an increased demand from the European market [108]. After 1993, the European market decreased, owing to the cereal feeds support policy and the Thai cassava chips and pellets were unable to compete with this. The main alternative markets were China and South Korea, but demands fluctuated, the domestic market became oversaturated [106] and the production declined.

Since the early 2000s, the cassava area has expanded by 40%, while yields have increased by roughly 20%. This expansion could be related to increased interest for starch, modified products, and utilization of cassava pellets for ethanol and liquor in China [108]. The post-2000 intensification was partly driven by technological advances in cassava varieties, mainly development of larger non-food varieties for bioethanol production.

Vietnam

Following a stagnant period from 1960 to 1975, the cassava area saw a short boom, with a 250% expansion from 1975 to 1980; yield levels were constant. In the period 1980–2000, the cassava area contracted to 50% of the 1980-area, with modest dynamics in yields. Since 2000, the area increased roughly 250%, as did yields. These large increases in area, yield, and eventually in production from 2000 have multiple reasons, including improved agricultural and processing technologies, governmental support, introduction of high yielding varieties as well as collaboration with international organizations [115]. Most of the production is exported to China. The demand for cassava is expected to rise even further, partly due to a governmental decision to focus on cassava for bioethanol production [125].

Cambodia

The cassava area expanded from almost none in 2000 to almost 390 000 ha in 2016, with a minor contraction between 2011 and 2014. The fast development can be explained by a sharp increase in demand and feedstock prices [120]. Simultaneously, the yields saw a steep increase by 400%. The area and intensification boom is closely related to a sharp increase in demand and prices for carbohydrates, driven by a combination of biofuel feedstock demand, animal fodder, and increasing use of cassava starch as a component in industrial food production. Similarly, the partial area stagnation from 2011 to 2014 could partly be a response to the general collapse of agricultural commodity prices on the world market in late 2008 [113], in addition to trade disputes with Thailand that have imposed both tariffs and non-tariff barriers to protect domestic producers [119].

Laos

The area and quantity of cassava produced in Laos remain negligible.

Rubber

Cambodia

FAO rubber statistics for Cambodia appear erratic and in very low numbers. Hence, we do not discuss them here. However, a recent remote sensing analysis shows establishment of 28,000 km² from 2006–2014, compared to a 2003 baseline of 1,005 km [26].

Vietnam

Natural rubber is Vietnam's second-largest exporting agricultural commodity, after rice. Following an apparently unsuccessful introduction of rubber in Vietnam from 1960 to 1980, the cultivated area expanded by almost 700% from 1990 to 2014 with a concurrent yield increase of 240%. The expansion process has a clear political driver in Decision 750/QD-TTg, endorsing the 2015–2020 Rubber Development Strategy of 2009 to increase the rubber area to 800,000 ha by 2020 [116]. The yield intensification can be attributed to improved practices and introduction of high yielding clones. Due to fluctuating global rubber prices, the Ministry of Agriculture and provincial authority has taken actions to limit oversupply by controlling rubber production, inter alia; new planting/investment in rubber has decreased since 2013, and no new land certificate has been given for new rubber cultivation [109]. The rubber area is distributed equally among smallholders and large-scale plantations [118], with large-scale plantations favored by the government and funded by domestic investors [53].

Thailand

Between 1960 and 1980, the Thai rubber area tripled, while yields were stagnant, likely caused by technological and information shortcomings, including planting of unsuitable clonal varieties, mismanagement, or expansion of rubber into marginal and unsuitable lands. During the three decades from 1980 to around 2007, rubber expanded by 100%, while yields soared by 500% until 2000. The post-1980 expansion and intensification is mainly brought about by the introduction of new high-yielding rubber clones distributed freely along with chemical inputs and smallholder access to credits [26], and an increased global demand for latex and consequently favorable world market prices. From 2010 to 2016, area expanded an additional 50%, while yields only saw minor fluctuations. About 90% of the rubber is produced by smallholders [122]. To date, Thailand remain the world's leading latex producer.

Laos

FAO does not provide statistics on rubber in Laos. The following is based on published insights. The first rubber plantations in Laos were established in 1994, but plantations at a larger scale did not emerge before mid-2000. Most of the rubber plantations are found in the northern provinces and mostly consist of independently owned, contract-farming-based operations, whereas concession models dominates in the southern part of the country [100]. The absence of concessions in the north is partly due to provincial authorities' resistance to large industrial plantations. In 2005, three northern provinces (Luang Namtha, Bokeo, and Oudomxai) formed an official consensus and decided not to give land concessions to rubber investors. Instead, contract farming was to be promoted with a general profit-sharing scheme of villagers obtaining 70% and investors 30% [121]. This was followed by a national moratorium on concessions in 2007, which was reinforced in 2012 [26,101].

Spiking prices of latex in the 2000s resulted in a surge of smallholder plantations that were met with an increased influx of foreign investments [102]. Most of the investment in Laos has been into regions adjacent to the country or origin of investment—e.g., Chinese companies have invested in the north, Thai companies in the central provinces, and Vietnamese companies in the south [102]. Since the early 2000s, rubber cultivation has been promoted by the provincial and national governments for example by direct subsidization of rubber cultivation and tax exemptions. The policies to stabilize shifting cultivation have also encouraged establishment of rubber plantations, as these policies have pushed farmers to find permanent alternatives to shifting cultivation or risk losing their land [121].