Using system dynamics to identify leverage points to reduce fruit and vegetable losses in Bihar, India

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Why map the causes of food loss?

The average daily per capita consumption rate of fruits and vegetables (F&V) in the state of Bihar is estimated to be only 35-45% of the international recommendation of 400 grams/capita/day — with rural rates ~12% less than urban.[1,2,3] Food loss rates estimated to be up to 40% of total production further exacerbate barriers to equitable F&V access, which include smallholder fragmentation and lack of coordination, the strengthening pull of urban markets, and the underdeveloped state of rural transport, market and storage infrastructures.[4, 5]

Whilst multiple studies have depicted various national-level drivers of food loss as linear decision chains between farm and fork,[6, 7, 8] little is understood about the feedbacks, delays and trade-offs driving food losses in Bihar. We utilise food systems approaches to map the perceived causes and consequences of food losses, aiming to identify leverage points to reduce food losses and improve the equitable distribution of F&V.

Above: Burnt unsold banana crops at Bazar Samiti, Patna.

Below: Different grades of eggplant at a retail market in Patna

Methodology

We conducted a series of telephonic interviews with stakeholders across the horticultural value chain: 13 farmers, 4 'aggregators'[4], 3 commission agents, 4 wholesalers, 1 retailer, 3 consumers and 3 key informants. Participants from Nalanda and Bhojpur districts were purposefully sampled for their rounded knowledge of the value chain. We then coded the causal relationships present within the transcripts as per the approach of Kim and Andersen (2012), before developing causal-loop diagrams (CLD) to map the causes, consequences and feedbacks associated with F&V loss (Figure 1).

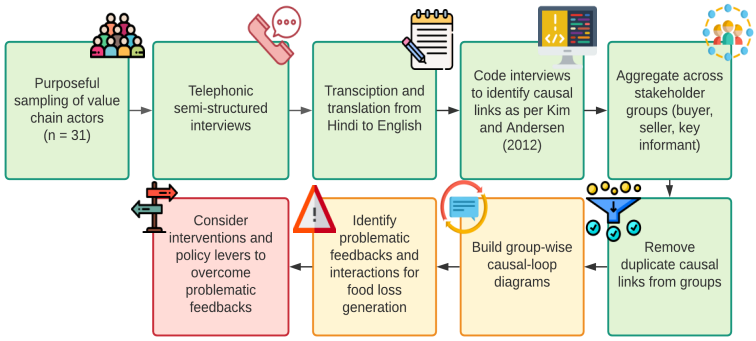

Figure 1: Workflow of the approach designed to map the perceived causes of F&V loss in Bihar, India. Green = completed; orange = ongoing; red = pending.

Results and implications

The 31 interviews identified a total of 230 causal relationships. '*Late market arrival*' was the most common (n=10), perceived to be associated with higher risks of F&V heat exposure, and the unavailability of wholesale traders later in the day. Of the causes external to system actors, extreme rainfall and cold weather were the joint most commonly perceived causes (n=5).

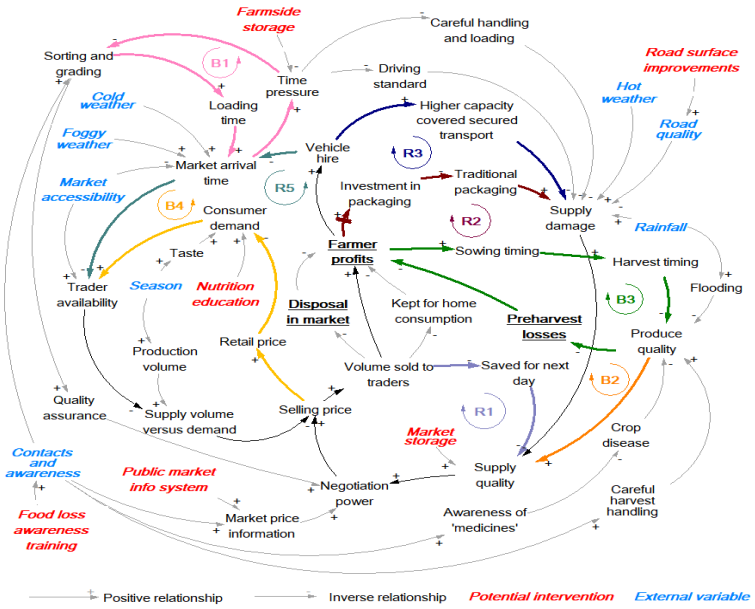

Figure 2: The feedbacks underpinning F&V losses in Bihar, as perceived by farmers and aggregators. Feedbacks: B1—Grading produce delays market arrivals, which discourages future grading ; B2–Produce harvested later in the season is perceived to be less fresh, meaning farmers plant earlier the next year; B3—Leaving produce in the field due to poor expected prices can increase the risk of pre-harvest losses; B4—Balancing feedback between supply, prices and consumer demands; R1—Farmers may refuse to sell at low prices in order to save it for the next day, further degrading F&V quality; R2—Farmers that invest in plastic crates and wooden boxes can reduce losses and improve profits, enabling further investment; R3—Farmers that hire secure vehicles can reduce losses and improve profits. B=Balancing feedback; R=Reinforcing feedback.

The perceived causes of F&V loss form a complex web of **feedbacks** (Figure 2), which cover multiple stages of the value chain: (i) pre-harvest (e.g. crop diseases and waterlogging), (ii) transport to market (e.g. moisture damage or improper handling), and (iii) at the market (e.g. exposure to heat whilst negotiating prices). The feedbacks operate across different time-scales; e.g. with '*R1*' operating at the sub-daily scale, and '*R2*' requiring farmers to invest over multiple weeks or months (signalling a potential poverty trap). The **trade-offs** which emerge suggest that food loss is a 'wicked problem': e.g. the quality assurance of F&V graded at the farmgate encourages traders to offer better prices, but the grading process can delay market arrival. The feedbacks are also moderated by various **external drivers** which operate beyond the influence of system actors (e.g. climate extremes and transport infrastructure), pointing towards the need to **intervene** across the wider enabling environment to improve rural market infrastructures, increase (cold) storage accessibility, and increase information availability to inform marketing decisions.

Conclusions

1. Causes of F&V loss in traditional horticultural systems may be highly non-linear: operating across multiple time-scales, and linked to downstream market and consumption dynamics.
2. Early analysis suggests that interventions must target multiple locations in the system to reduce pressures and trade-offs induced by inadequate market, transport and storage facilities.
3. Insights from the key informants and market buyers (e.g. retailers and consumers) will further the identification of problematic feedbacks and potential solutions.

References: [1] FAO & UN (2014); [2] NSSO (2013); [3] Dizyee & Rich (2016); [4] Cooper et al. (2021); [5] Kumari et al (2017); [6] Gokurn & Kuthambalayan (2017); [7] Gardas et al. (2017); [8] Balaji & Arshinder (2016)

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