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*Commission*

WORKING PAPER

# Briefing Note: Food Production Systems across North India

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# Briefing Note: Food Production Systems across North India

Alison Laing and Yacob Beletse

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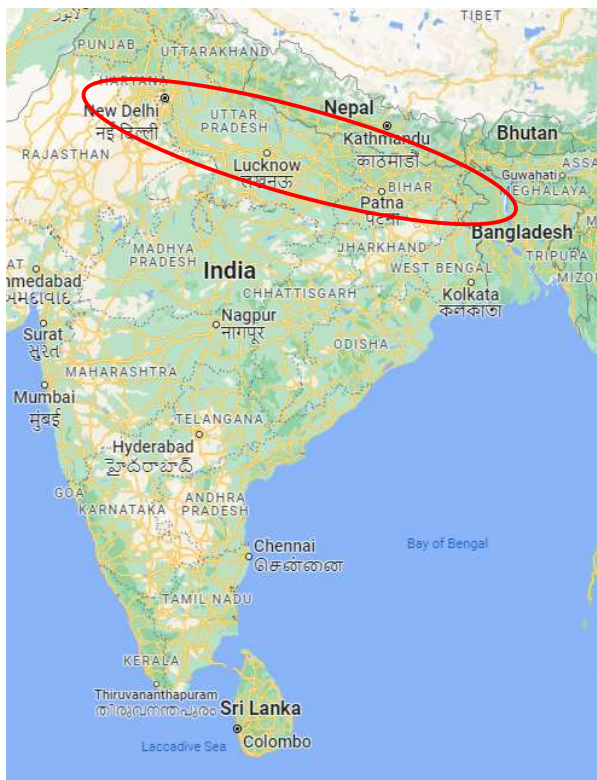
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## 1.1 Acronyms used in this note

BAU	Business as usual
CLEM	Crop Livestock Enterprise Model, a farming system model developed by the CSIRO
CSIRO	Commonwealth Scientific and Industrial Research Organization
Gol	Government of India; the central (federal) government of the country
LGP	Lower Gangetic Plains, an agroecological region of north India encompassing much of the state of West Bengal
MAgPIE	Model of Agricultural Production and its Impact on the Environment, a land use allocation model applied in India by the Indian Institute of Management, Ahmedabad and PIK
MGP	Middle Gangetic Plains, an agroecological region of north India encompassing much of the state of Bihar
SDP	Sustainable Development Pathways
TGP	Trans Gangetic Plains, an agroecological region of north India encompassing much of the state of Punjab
UGP	Upper Gangetic Plains, an agroecological region of north India encompassing much of the western region of the state of Uttar Pradesh

## 1.2 Introduction

The Indo Gangetic Plain (IGP; Figure 1) stretches from eastern Pakistan to north-western Bangladesh, encompassing the terai foothills in Nepal and the northern states of India. The IGP is a key food producing region, providing within India, employment and the means of producing food for hundreds of millions of people, many of whom live in rural poverty (Ericksen et al., 2011).



Households living in the Indian IGP are diverse, with high variation in agroecologies, climates, landholding size and risk tolerance. This variability in turn leads to differences in farm production systems, for example in the extent to which mechanization and manual labour are used on farm, the diversity of activities undertaken on the farm, or whether the farming household's focus is primarily on producing food products for household subsistence or farm products (the majority of which are foods) for sale.

Farming system productivity is a key determinant of food security at both household and national scales. While many rural areas experience food insecurity, at a national level India produces sufficient basic foodstuffs to feed its population. Current production levels are affected by external drivers including weather events and international conflicts; throughout 2023 the Government of India (GoI) has restricted exports of both wheat and rice to support greater domestic supply.

In many parts of India, particularly in urban areas, increases in non-communicable diseases such as heart disease, diabetes and kidney failure have been observed. These have been correlated to increased availability of packaged and ultra-processed foods, increased consumption of meat, other high-fat animal products and sugars, and reduced consumption of whole grains. The effect of these changes in diet can be observed in agricultural production systems, where demand for sugarcane, dairy products, poultry and maize for livestock feed keeps the price of these raw products high and attractive to farmers.

While much research has been undertaken into the production, management and economics of key *crops* and *cropping systems* within India, there has been relatively little research at the *farm scale* to quantify whole farm production systems in terms of their productivity, labour requirements and production economics. In addition, there is little information about the likely effects on these three factors of continuing current farm management practices into the future, or the farm-level effects of altering production systems so that Indian farmers produce foods for domestic consumption nationally which are more aligned to the dietary principles recommended in the EAT Lancet dietary guidelines (Willett et al., 2019). In this briefing note we provide an overview of i) the development of 16 household typologies

representing the range of diversity of farming systems across the Indian IGP; ii) baseline farming system scenarios developed using the CLEM farming systems model; and iii) farming system scenarios of future production systems with either a business as usual (BAU-) or an EAT focus.

### 1.3 Household typologies

Much of the Indian IGP spans four agroecological zones:

- The Lower Gangetic Plains (LGP) in the north east which includes much of the state of West Bengal
- The Mid Gangetic Plains (MGP) further west, including the states of Bihar and eastern Uttar Pradesh
- The Upper Gangetic Plains (UGP) west of the MGP, including western Uttar Pradesh
- The Trans Gangetic Plains (TGP) in the north west, spanning much of the states of Haryana and the Indian Punjab

There are strong gradients east-west along the Indian IGP, with significantly higher annual rainfall in the east compared to the west, and greater availability (although not necessarily access to) water for irrigation. In general, soils are more fertile in the eastern IGP, as they are more alluvial in nature and draw nutrients from sedimentary deposition from the big rivers flowing through the region.

Social differences exist too: households in eastern Indian states are poorer and contain more family members than those in the north western states; landholding sizes are larger in the north west, farming households have greater capacity to take on and service debt, and consequently have higher levels of access to machinery and irrigation water.

The Gol (2019) has categorized agricultural landholdings into five categories: these are shown in Table 1 along with the prevalence of each category in each of the four agroecological zones spanning the Indian IGP.

**Table 1: Landholding size and prevalence across the IGP of five agricultural landholding categories**

Category	Landholding size (ha)	Distribution (%) within the...			
		...LGP	...MGP	...UGP	...TGP
Marginal	≤ 1.0	82.8	91.2	80.2	14.1
Small	1.0 ≤ 2.0	13.4	5.8	12.6	19.0
Semi-medium	2.0 ≤ 4.0	3.5	2.5	5.5	33.7
Medium	4.0 ≤ 10.0	0.3	0.5	1.6	27.9
Large	> 10.0	0.01	0.02	0.1	5.3

Data source: Gol, 2019

Within the LGP, MGP and UGP over 80 % of households were Marginal, with between 5 and 13 % of households Small, 5 % or less Semi-medium, less than 2 % of households Medium, and less than 1 % of households in the Large category. In contrast, in the TGP the distribution of households between Small, Semi-medium and Medium was more even, ranging between 19 to 34 %, with 14 % of households Marginal. One of the main reasons for the small landholding sizes is the increasing land fragmentation through inheritance of a portion of an older relative’s landholding.

The four categories Marginal, Small, Semi-medium and Medium were used to develop four household typologies within each agroecological zone, ensuring that these represent both the majority of farming households within each zone and also realistic variability between households. In terms of the average farm size across the Indian IGP, Gol data show that there is relatively little difference within each agricultural category, although farm sizes are considerably larger (average 4.8-5.7 ha) for Medium households than for Marginal households (average 0.3-0.6 ha; Figure 2). No disaggregation by gender has been done in the typologies as across these agroecological zones women-headed households made up 8-15 % of all



households. In total there were 16 household typologies, representing the four most common agricultural categories in each of the four agroecological zones.

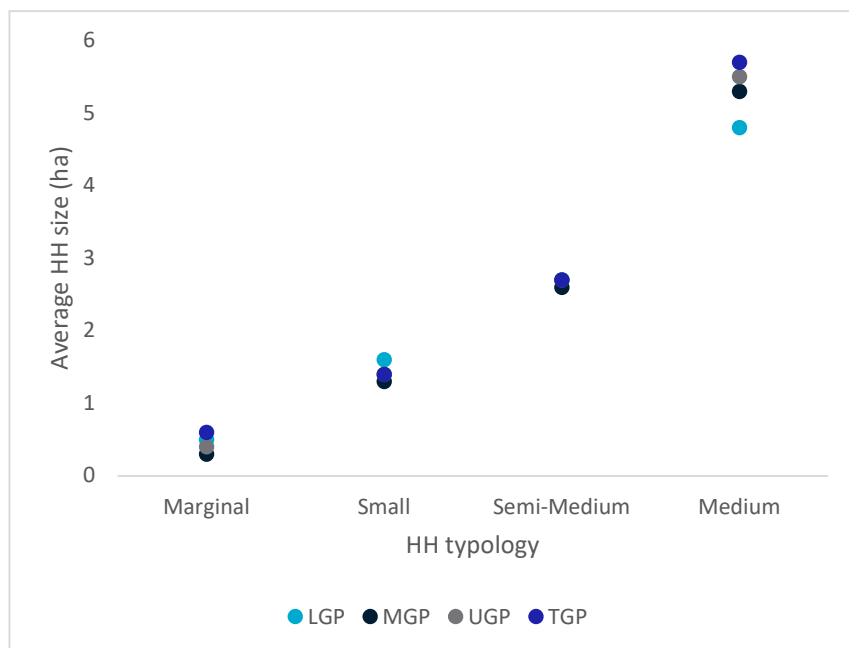


Figure 2: Average farm size across the Indian IGP for households in each landholding category

## 1.4 Farming system scenarios

The Crop Livestock Enterprise Model (CLEM; [www.apsim.info/clem](http://www.apsim.info/clem)) was used to model the 16 different farming systems under baseline and two future scenarios, representing a business-as-usual (BAU) agricultural-management scenario and a sustainable-development-pathway (SDP) scenario in which farm production was more aligned to producing the foods recommended for a healthy and sustainable diet by the *Eat-Lancet* Commission (Willett et al., 2019).

**Baseline farming system scenarios** were developed for each agroecological zone, using GoI statistics to identify those crops and livestock which were most widely produced in each zone. Within each agroecological zone farming systems were similar across household types, reflecting the common agroecologies, climates, soils and cultural and social expectations within each zone. The key crop and livestock components of the farming systems in each zone are shown in Table 2. Across the four household types within each agroecological zone yields varied, reflecting differences in landholding size, ability to access inputs such as fertilizers, irrigation water and plant protection chemicals. As well, the labour required to tend crops and livestock varied with richer households (i.e. Semi-medium and Medium, as well as those in the UGP and TGP) having greater access to mechanization. Labour and financial resources were non-limiting within the simulations, enabling quantification of the requirements of each in each household typology.

Table 2: Crop and livestock products from each agroecological zone

Agroecological zone	Crops produced	Livestock products
LGP	Wet season rice, dry season rice, wheat, mustard, potato, lentil, jute	Cow milk, fish, chicken eggs
MGP	Wet season rice, wheat, mustard, potato, gram, pigeon pea	Buffalo milk, fish
UGP	Wet season rice, sugarcane, wheat, mustard, lentil, pigeon pea	Buffalo milk
TGP	Wet season rice, high value (basmati) rice, wheat, mustard, potato, cotton	Buffalo milk, chicken eggs, chicken meat

Input data for 10 years for the most common type in each agroecosystem (i.e. the Marginal household in the LGP, MGP and UGP and the Semi-medium household in the TGP) were sourced from APSIM simulations, observed data and literature. These data were scaled up and/or down for other agroecosystems depending on the relative differences between average crop yields across agroecosystems: for example, in the TGP the scaling factors for the Marginal, Small, Semi-medium and Medium household types were 0.7, 0.8, 1.0 and 1.3, respectively, as the Semi-medium household type is most widespread. In all other agroecological zones the scaling factors were 1.0, 1.2, 1.5 and 2.0, respectively, reflecting that the Marginal household is most common in these zones. Similar scaling of livestock numbers was undertaken.

**Future farming system scenarios** were developed using output from national-scale MAgPIE modelling conducted by the Indian Institute of Management-Ahmedabad and PIK and represent BAU and SDP pathways. Key trends in these pathways are shown in Table 3.

**Table 3: Trends of key variables under BAU and SDP futures**

Variable	Trend under BAU	Trend under SDP
Cereal crops	Reduced yields due to inefficiencies in management, poor soil health and high production costs	Increased yields due to improvements in agronomic management, soil health and more efficient production systems offsetting higher costs
Sugar	Increased yields reflecting market demand and high prices	Reduced yields reflecting interventions reducing demand
Other crops	Slight increase in oil, pulse, fruit and vegetable crops; decrease in potatoes and pulses	Increase in oil, pulse, fruit and vegetable crops; decrease in potatoes
Dairy production	Increased production	Decreased production
Red meat <sup>1</sup> production	Increased production	Decreased production
Egg & poultry meat production	Increased production	Increased production
Overall land productivity	Unchanged from present day	Increased
Mechanization	Little available, especially in poorer households	Highly mechanized
Labour required for crops	Required especially for transplanting and post-harvest processing	Most crop management mechanized, little labour needed
Labour required for livestock	Requirements similar to present day	Requirements unchanged but livestock cultivation reduced so less labour required
Water use efficiency	Inefficient use of water reducing crop yields while increasing production costs	Increased efficiency of water use: more water used, but over a greater area and for a higher yield
Nutrient use efficiency	Inefficient use of fertilizers reducing soil health while increasing production costs	Increased efficiency of nutrients and greater uptake of non-chemical fertilizers increasing soil health while reducing production costs without yield penalty

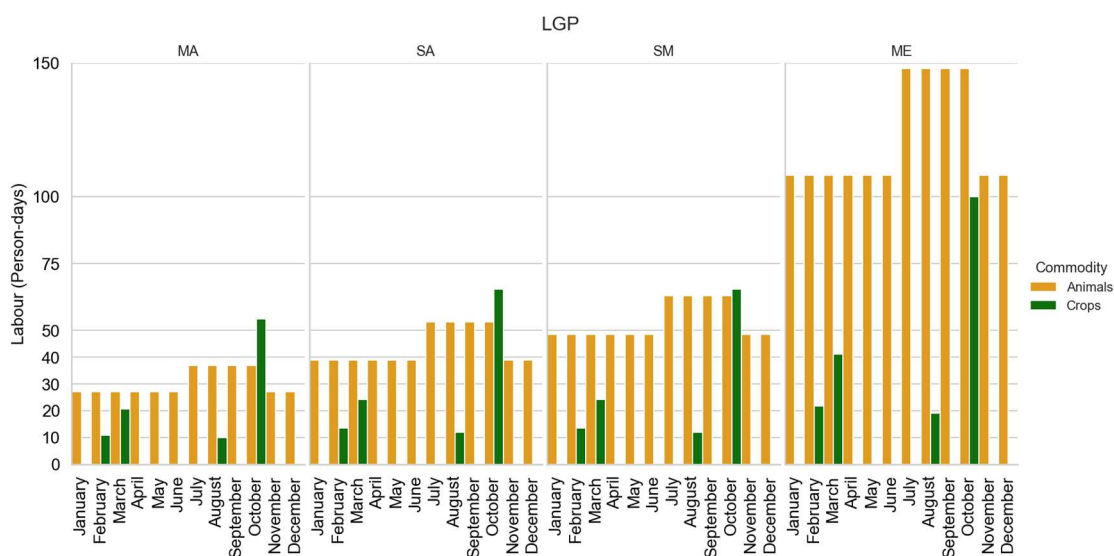
<sup>1</sup> Red meat production is primarily mutton and other small ruminants; currently these form a small part of diets and this is likely to increase under a BAU future and decrease under an SDP future. It is unlikely that large ruminants will be consumed

## 1.5 Simulation outputs

### 1.5.1 Baseline scenarios

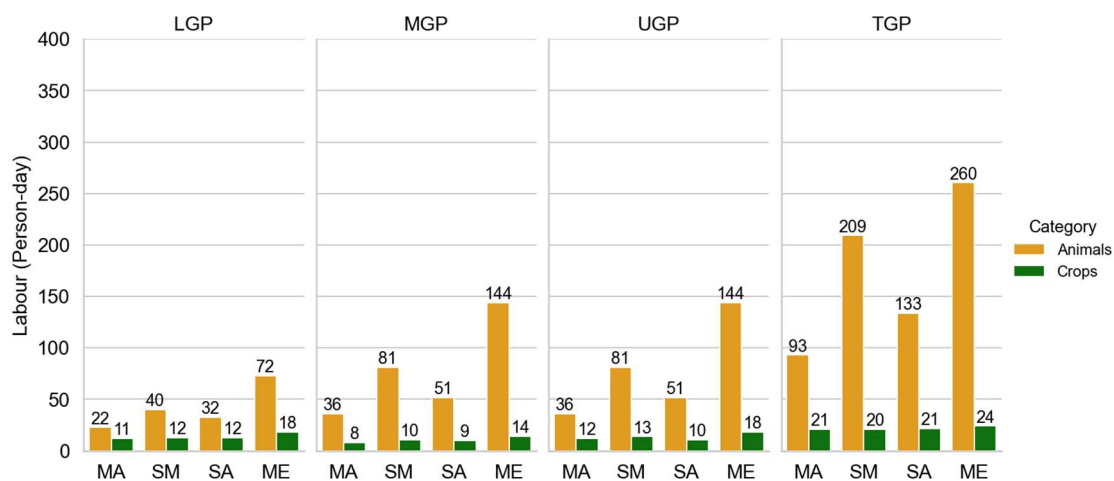
#### Labour across agricultural categories and agroecological zones

Similar trends in labour variability were observed across all four agroecological zones. Data shown in Figure 3 are for the LGP, with those for the MGP, UGP and TGP shown in Appendix I. Crops require labour intermittently throughout the year – primarily for land preparation, sowing, harvesting and post-harvest processing. Animal production requires more labour more often than crop cultivation – a certain amount is required to feed, water and clean animals daily, regardless of whether they are actively producing food products. At times additional labour is required – for example if milking is required, or if additional feed must be foraged to supplement more readily accessible feed options.



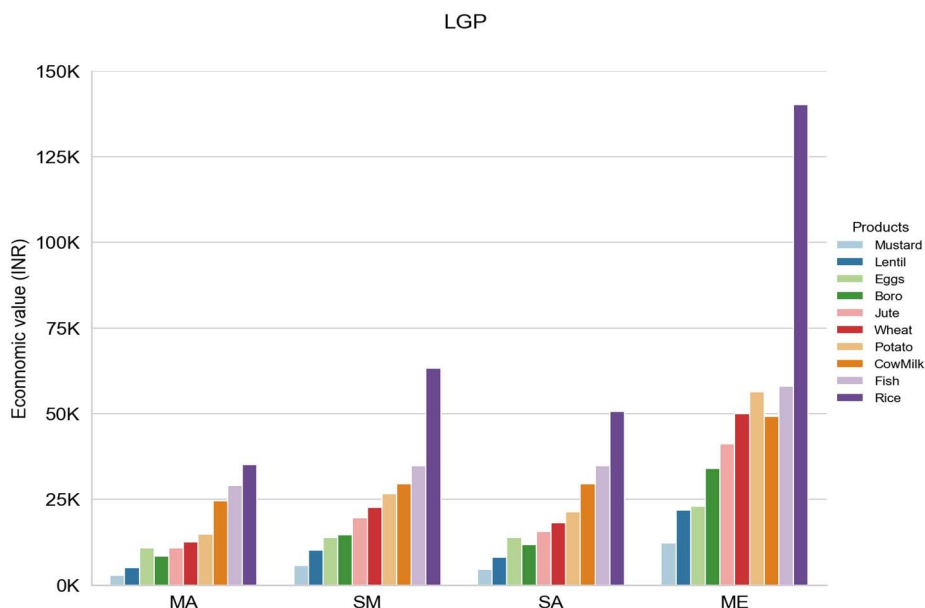
**Figure 3: Monthly labour requirements for animals and crops in the Lower Gangetic Plains (LGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**

Across all zones households with more assets (especially Medium household types) required more labour to operate the farm, as they crop a greater amount of land and husband more livestock (Figure 4). Relative to the LGP zone, labour requirements in the MGP and UGP zones are higher but comparable, whereas the labour requirements for households in the UGP are an order of magnitude higher. This is largely a function of the increased landholding size and livestock produced by farmers in the TGP compared to those in the other agroecological zones.



**Figure 4: Annual mean labour requirements for animals and crops across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

### Economic value of farm products

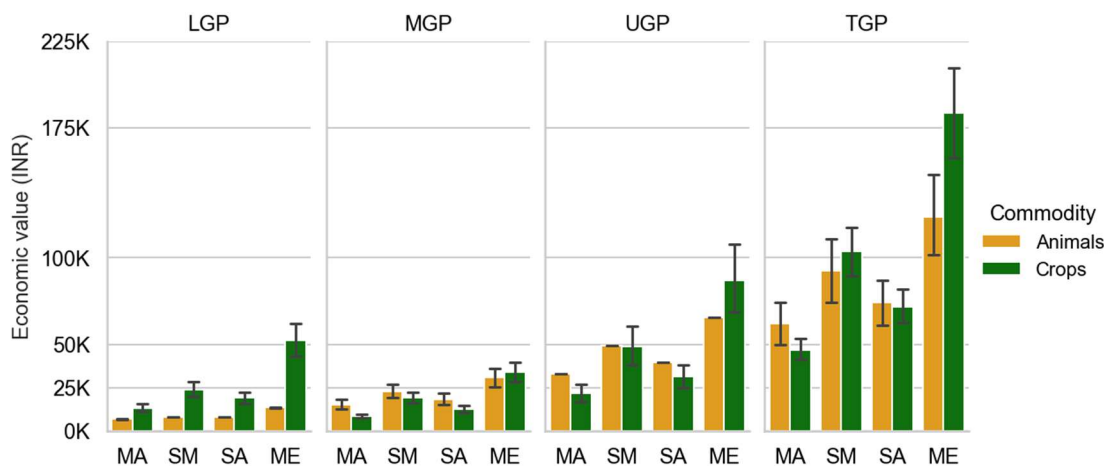


**Figure 5: Economic value of farm products in the Lower Gangetic Plains (LGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**

Across all agroecological zones consistent trends in the economic value of farm products emerge (Figure 5 and Appendix II). Animal products (e.g. cow milk and fish in the LGP) generally have a high economic value to the farm household. Cash crops such as jute (in the LGP) or sugarcane (in the UGP) have a high value, as do crops for which the Government imposes minimum price floors, such as wheat and wet season rice. In contrast, products which are produced in relative small quantities (e.g. mustard, lentil) or which are widespread (eggs) tend to have lower economic value.

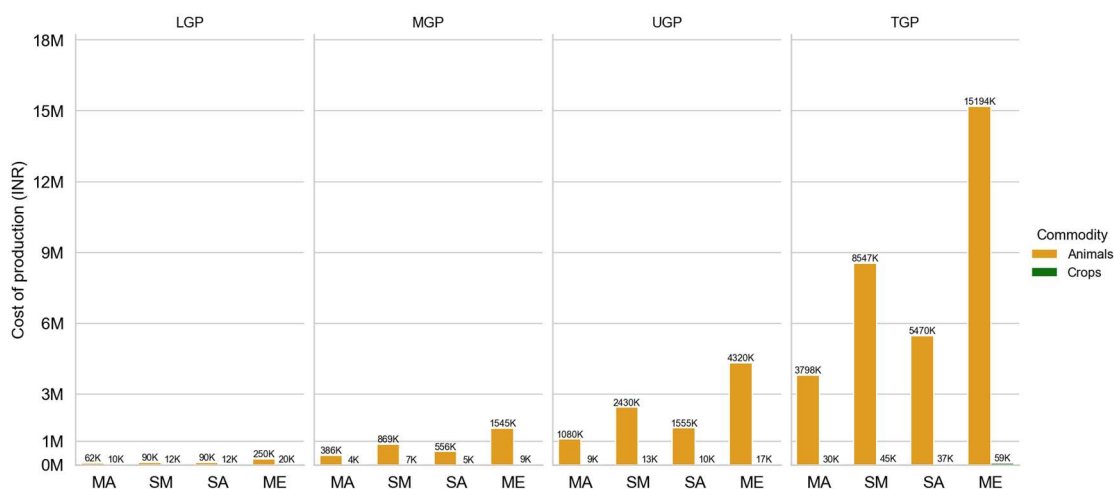
The economic value of farm products is greater for semi-medium and, especially, medium households as they have greater resources over which and with which to farm.

For all household types in the LGP and for the medium household types in the UGP and TGP the average annual economic value of crops produced on farms is greater than that of animal products. For the larger households in the UGP and TGP (i.e. the northern and northwestern regions of the Indian IGP) this reflects the trend to grow high value cash crops such as sugarcane and basmati rice, with a smaller focus on livestock grown at least in part to produce food products for home consumption. In the LGP smallholder farmers have very small farm sizes and cannot afford to house large numbers of animals; hence herd and flock sizes are smaller and make up a smaller proportion of the farm's economic value.



**Figure 6: Annual average economic value of farm products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

### Cost of production and gross margins

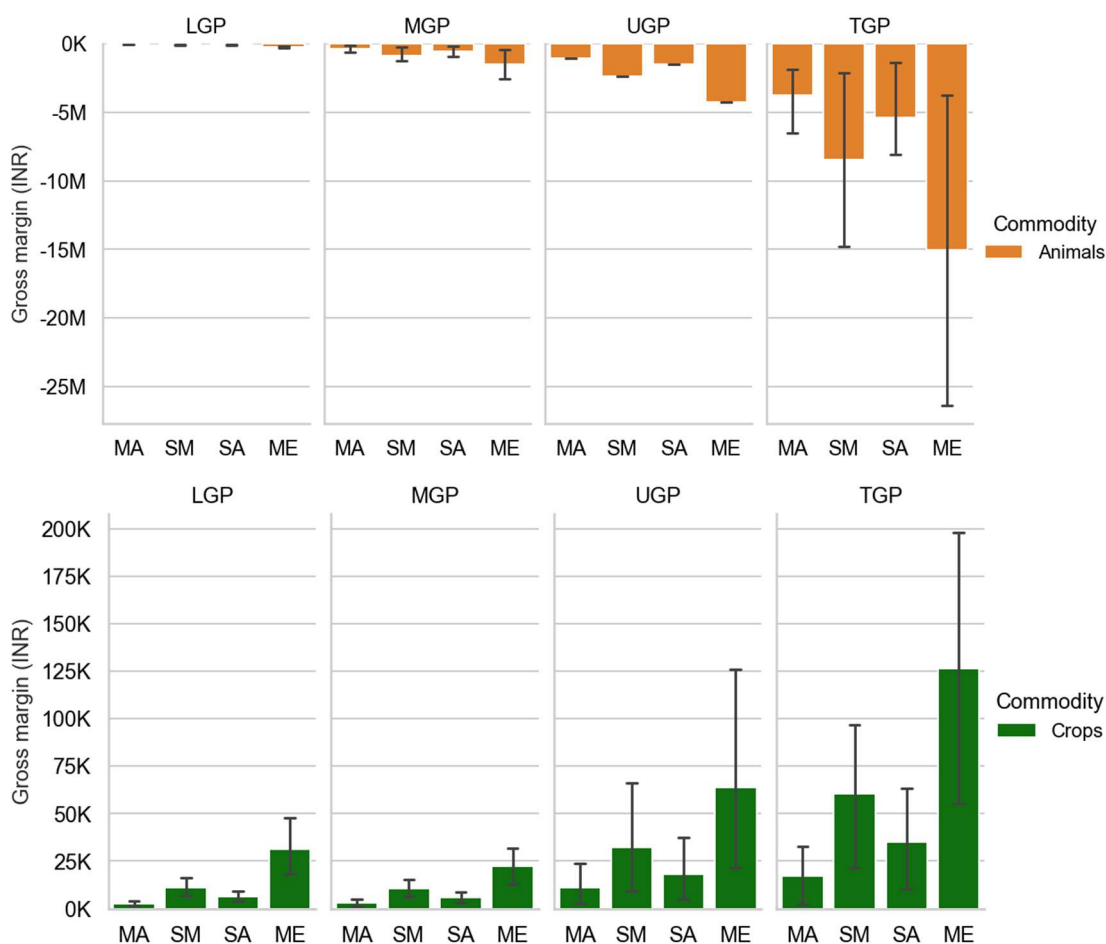


**Figure 7: Annual average cost of production for animal and crop products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

Production costs increase within each agroecological zone from marginal to medium households, and across agroecological zones, from LGP to TGP (Figure 7). Costs of producing animal products are considerably higher than those associated with producing crops: this is in part a reflection of the daily labour required to produce animals, relative to the smaller labour required for crop production.

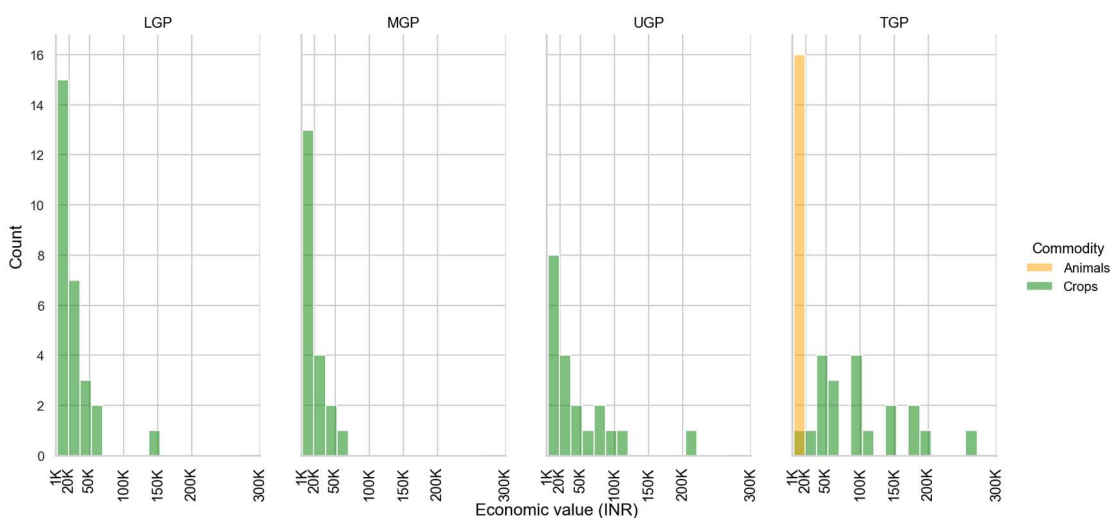
Animal products generate negative gross margins (i.e. the sale price of a product less its cost of production), with the size of the negative gross margin increasing across agroecological zones and across household types (Figure 8). As well as indicating the larger absolute herds and flocks kept by households with more land and/or in the more affluent north western Indian IGP, this may reflect that smaller and more marginal households cannot afford to lose money on farm products, whereas larger, richer households have greater capacity to offset losses elsewhere in the farm business and, if necessary, to obtain and service loans. It may be the case that livestock ownership in more affluent household types is a status symbol and being able to underwrite the costs of owning the livestock is part of the high status.

Across all agroecological zones and household types crop products generate positive gross margins, with again the magnitude of the gross margin increasing with zone and household type from small and marginal to larger and more affluent (Figure 8).



**Figure 8: Annual mean gross margins for animal (top) and crop (bottom) products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

Figure 9 shows those crop and animal products produced by each household type in each agroecological zone which have a positive gross margin, i.e. where the sale price of a product is greater than its direct production costs (indirect costs have been excluded from this analysis). In all four agroecological zones crops provide more positive economic value than animals to the farm, contributing between 1,000 to 150,000 INR in the LGP and between 1,000 and 275,000 INR in the TGP. In only the TGP do animal products provide any positive gross margin to the farm, and even there the value of the gross margin is low, at 1,000 INR (although the frequency of the animal products with positive gross margins is high).



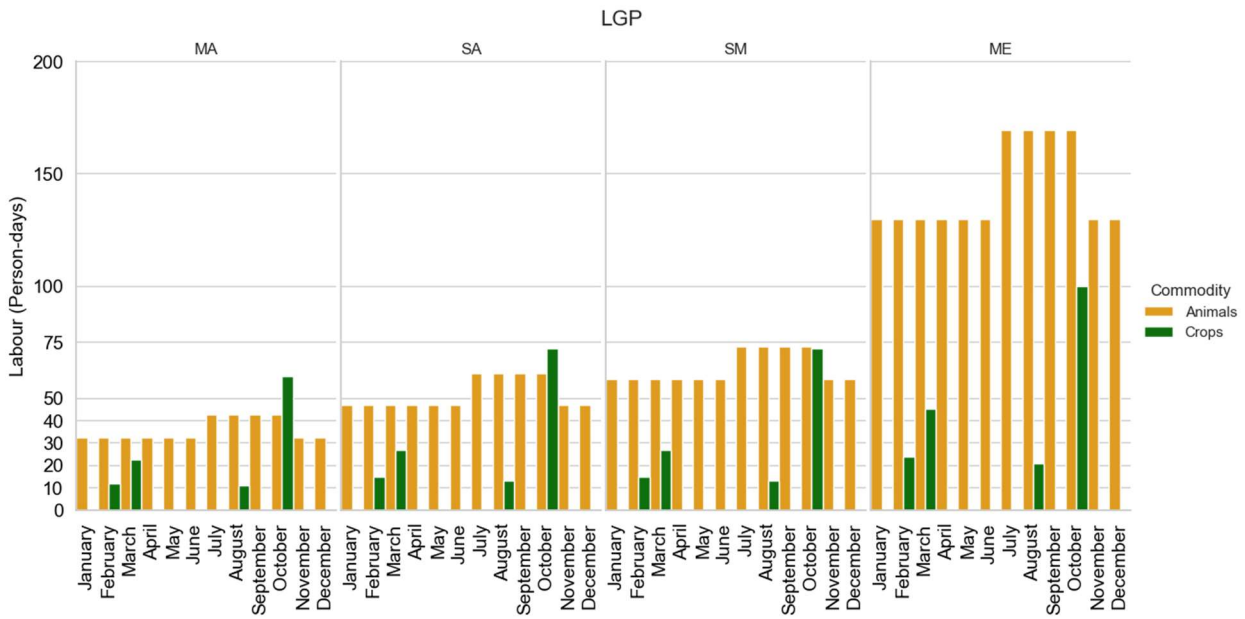
**Figure 9: Economic value of farm products with positive gross margins across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP). A column**

with a value of 15, for example, indicates that there are 15 products in that economic-value category whose economic value is within the range of that economic value.

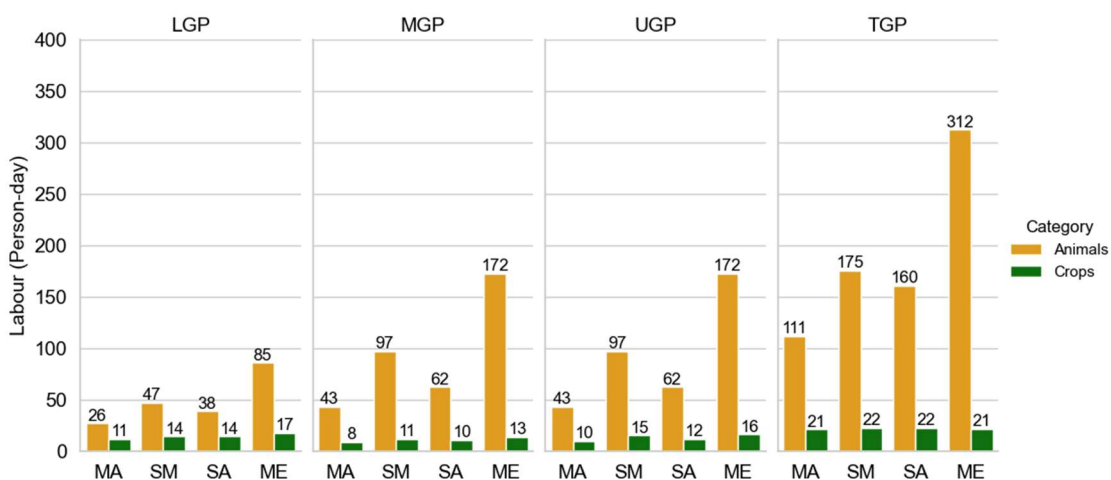
## 1.5.2 Future scenarios

### 1.5.2.1 BAU

The Business as Usual (BAU) scenario presents an increase in labour requirements (Figure 10 and 11), reflecting different agricultural outcomes and factors affecting labour demand. These changes can have implications for the efficiency and sustainability of agricultural practices in the future.



**Figure 10: Monthly labour requirements for animals and crops in the Lower Gangetic Plains (LGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**



**Figure 11: Annual mean labour requirements for animals and crops across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

Across all agroecological zones consistent trends in the economic value of farm products emerge (Figure 12 and Appendix IV). Animal products (e.g. cow milk and fish in the LGP) generally have a high economic value to the farm household. Cash crops such as jute (in the LGP) or sugarcane (in the UGP) have a high value, as do crops for which the government imposes minimum price floors, such as wheat and wet season rice. In contrast, products which are produced in relative small quantities (e.g. mustard, lentil) or which are widespread (eggs) tend to have lower economic value. The economic value of farm products, in general, follows similar trends to the baseline

For all household types in the LGP and for the medium household types in the UGP and TGP the average annual economic value of crops produced on farms is greater than that of animal products.

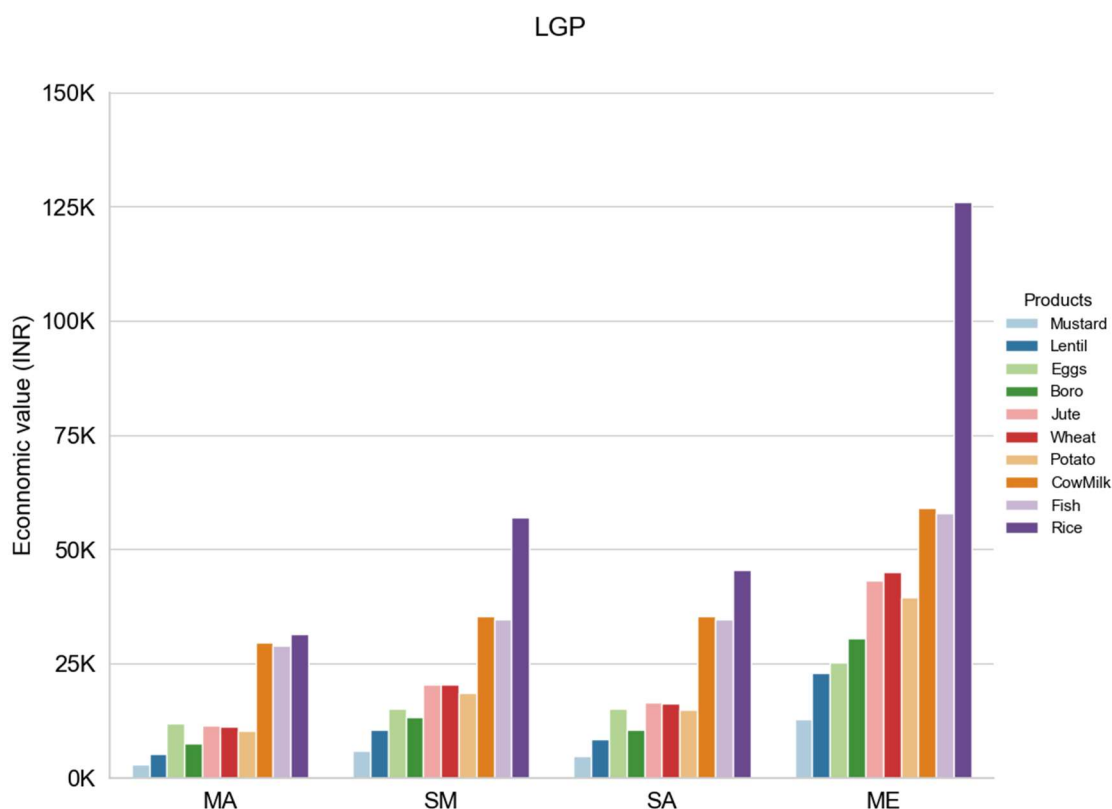


Figure 12: Economic value of farm products in the Lower Gangetic Plains (LGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.

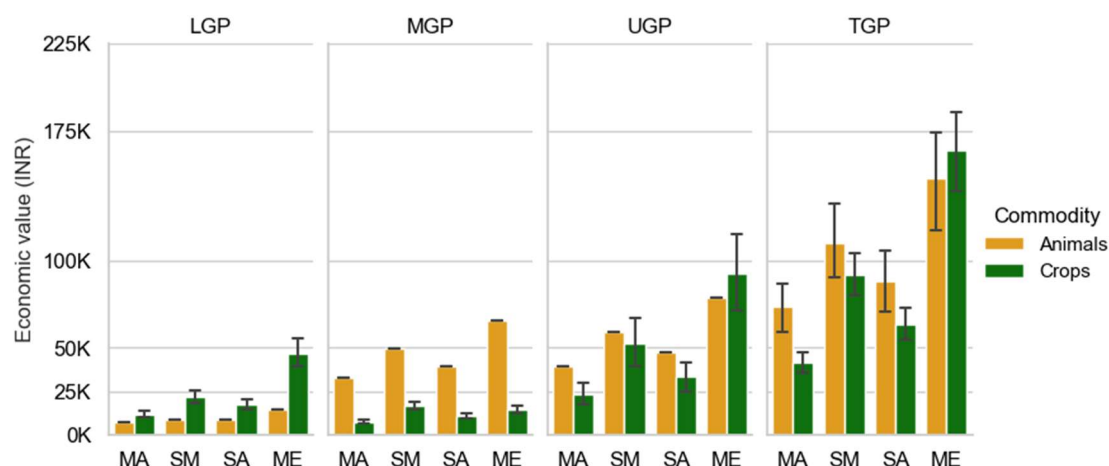
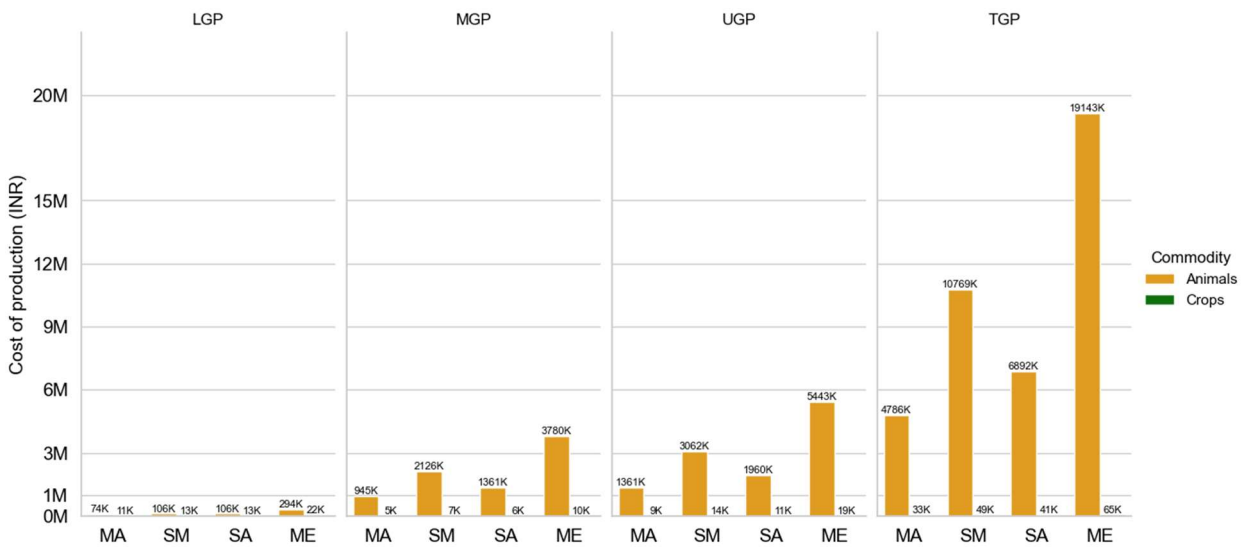


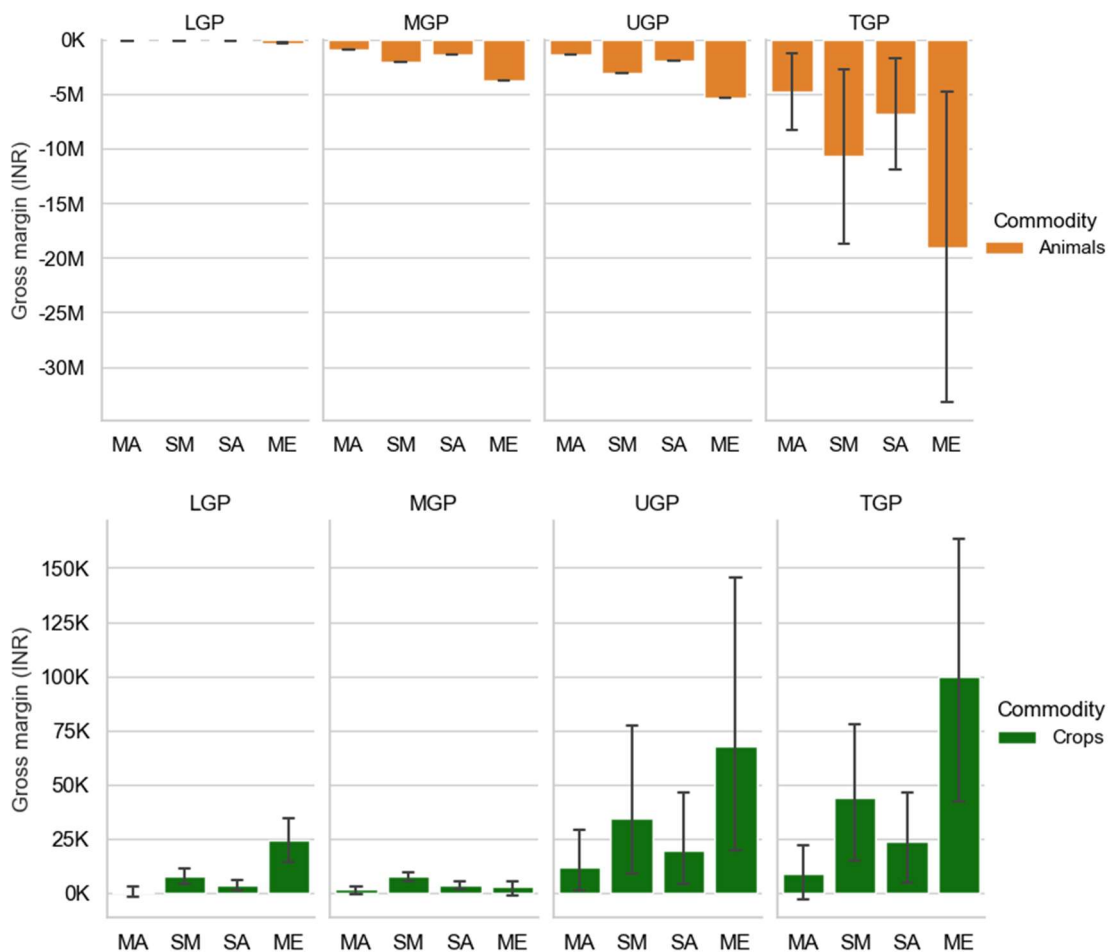
Figure 13 : Annual average economic value of farm products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.





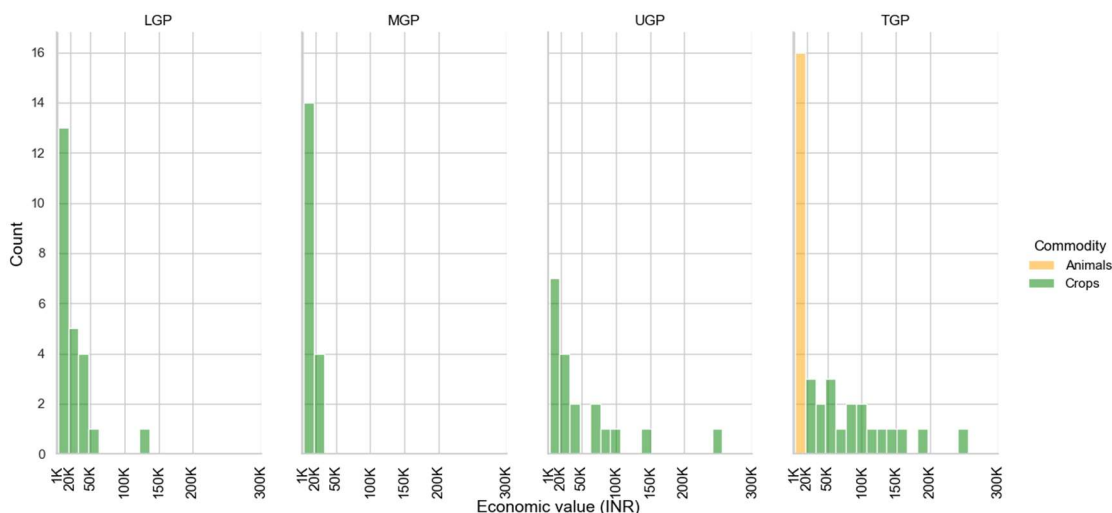
**Figure 14: Annual average cost of production for animal and crop products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

Figure 15 presents, there is higher possibility of generating negative gross margins in animal products (i.e. the sale price of a product less its cost of production), with the size of the negative gross margin increasing across agroecological zones and across household types. Across all agroecological zones and household types crop products generate positive gross margins but will be less than the baseline scenario, with again the magnitude of the gross margin increasing with zone and household type from small and marginal to larger and more affluent (Figure 15).



**Figure 15: Annual mean gross margins for animal (top) and crop (bottom) products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

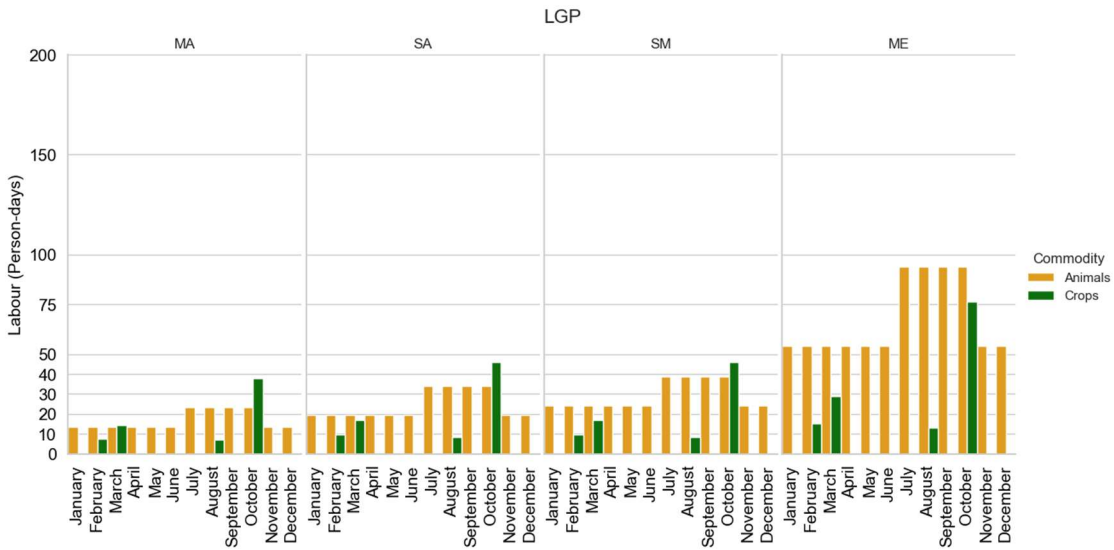
For the BAU, in all four agroecological zones crops provide more positive economic value than animals to the farm, contributing between 1,000 to 125,000 INR in the LGP and between 1,000 and 275,000 INR in the TGP. In only the TGP do animal products provide any positive gross margin to the farm, and even there the value of the gross margin is low, at 1,000 INR (although the frequency of the animal products with positive gross margins is high).



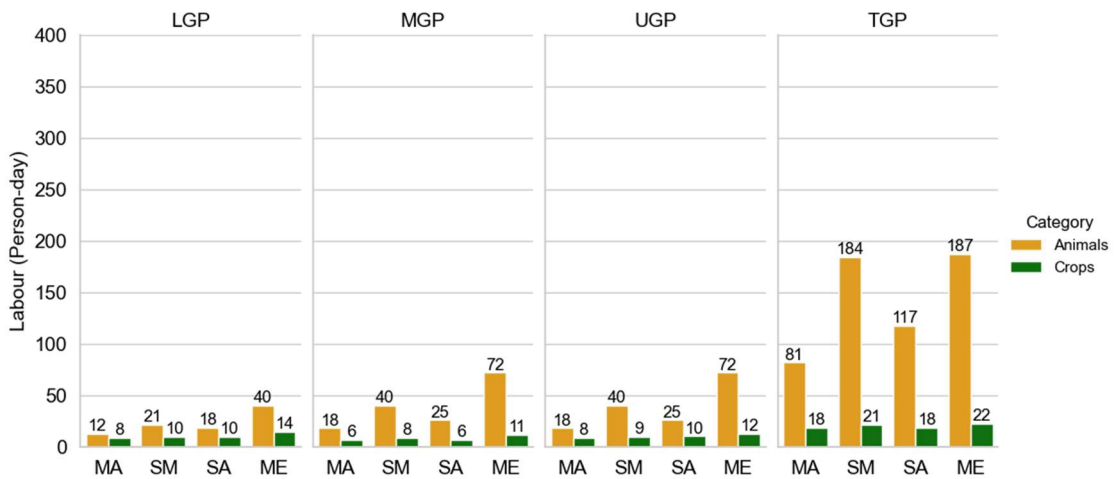
**Figure 16: Economic value of farm products with positive gross margins across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP). A column with a value of 15, for example, indicates that there are 15 products in that economic-value category whose economic value is within the range of that economic value.**

### 1.5.2.2 SDP

In the Sustainable Development Pathway (SDP) scenario, there is a notable reduction in the production of cow and buffalo milk when compared to the baseline (Figure 19). This reduction is paralleled by a decrease in labour dedicated to animal management (Figures 17 and 18). These decline in milk production and associated labour suggest a significant transformation within the livestock sector. This shift may signify a potential decrease in the economic value traditionally derived from livestock, particularly in the context of milk production. It raises the possibility of reduced reliance on livestock for economic sustenance, indicating a potential shift towards alternative agricultural practices or priorities aligned with sustainability and developmental objectives.



**Figure 17: Monthly labour requirements for animals and crops in the Lower Gangetic Plains (LGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**



**Figure 18: Annual mean labour requirements for animals and crops across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

### LGP

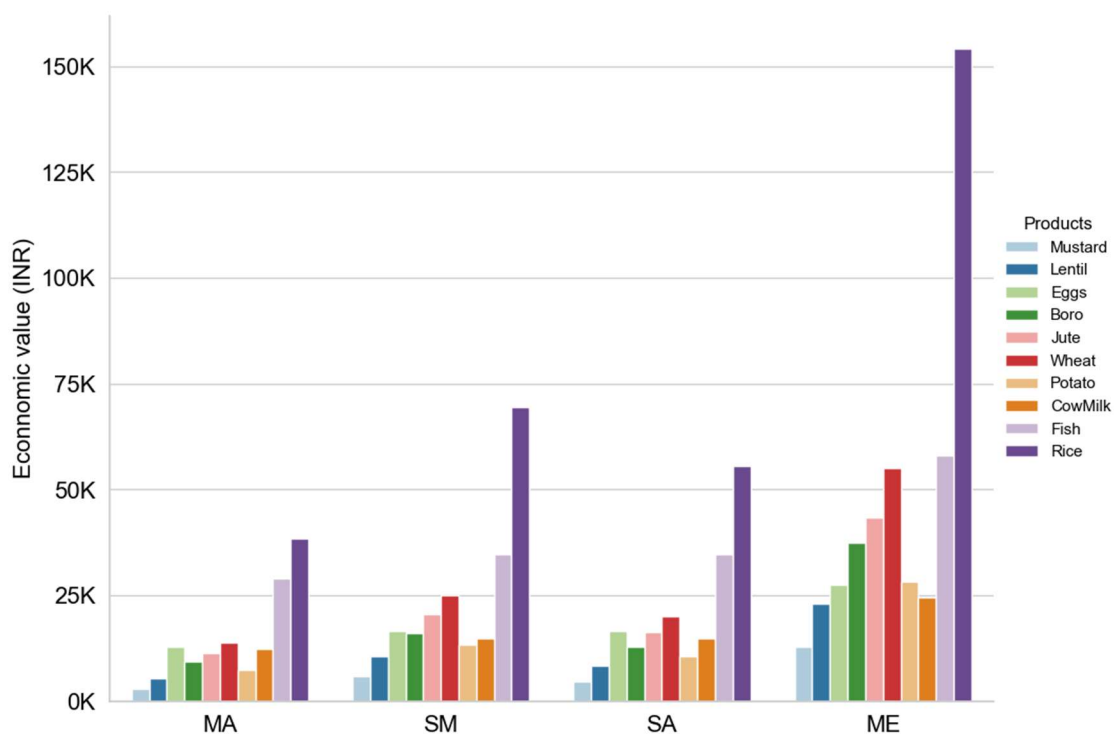


Figure 19: Economic value of farm products in the Lower Gangetic Plains (LGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.

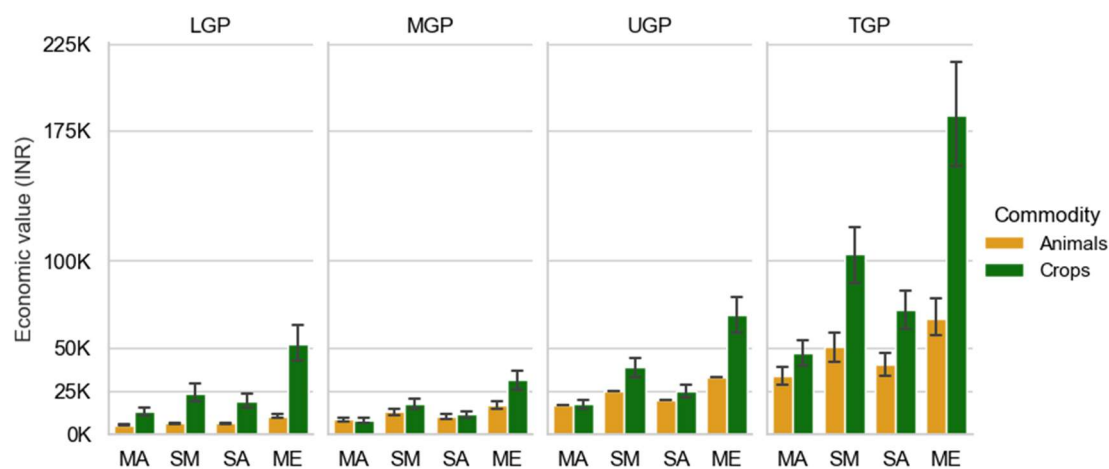
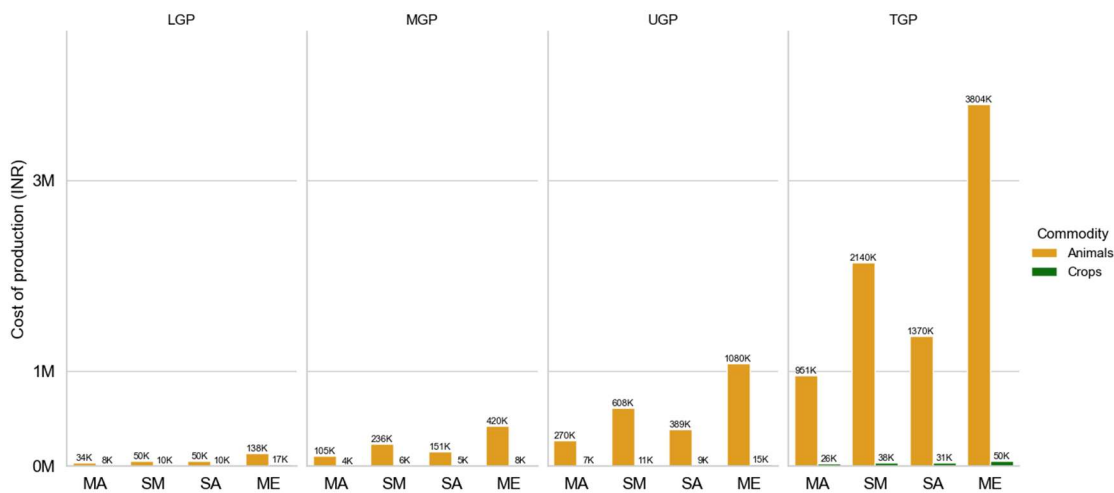


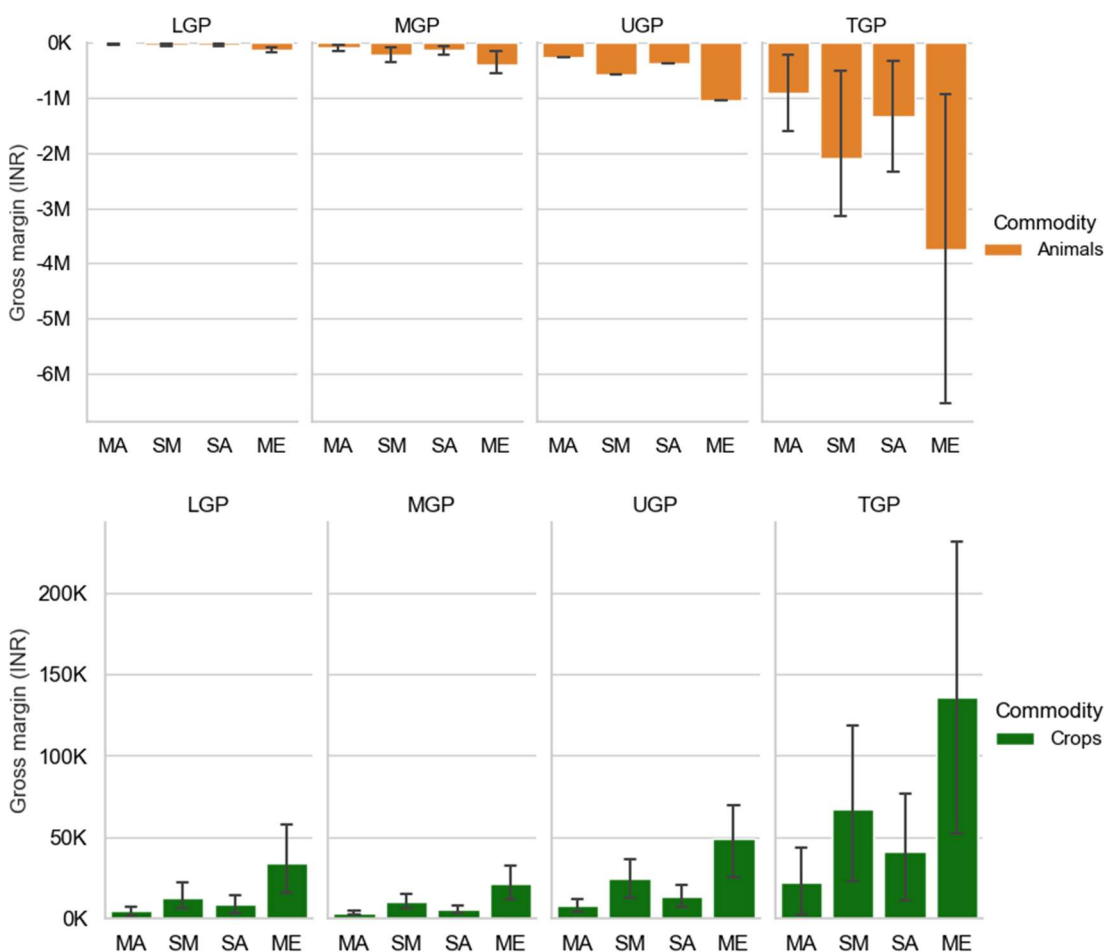
Figure 20: Annual average economic value of farm products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.



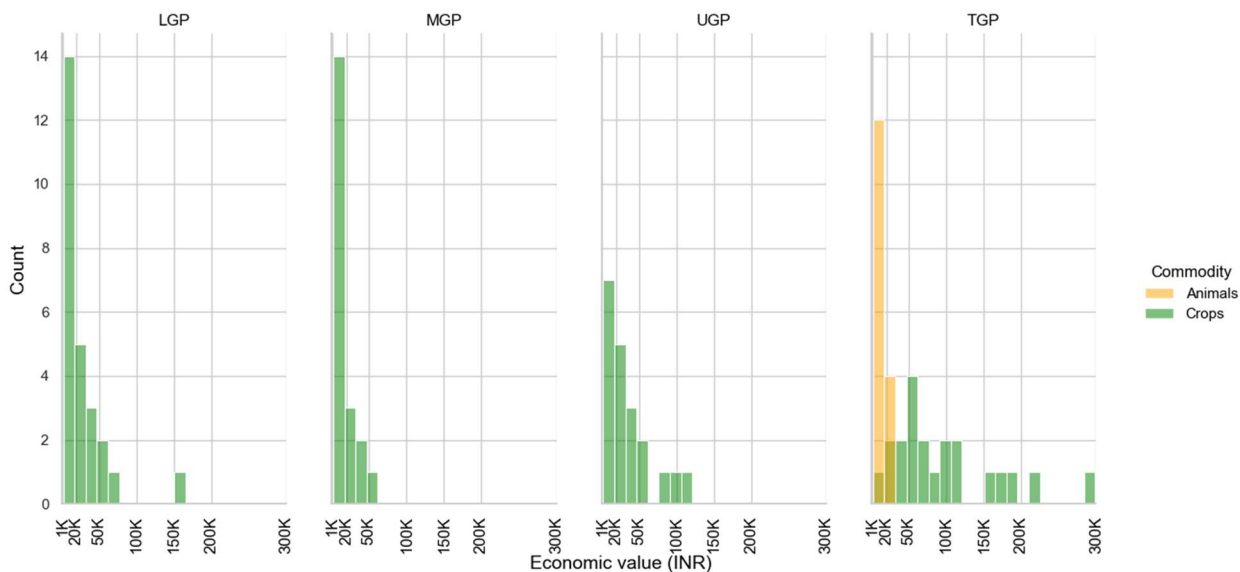
**Figure 21: Annual average cost of production for animal and crop products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**

In the SDP, the potential for negative gross margins in animal products, which represents the sale price of a product minus its production cost, is evident. These negative margins vary across agroecological zones and different household types, as depicted in Figure 22. However, it is noteworthy that the extent of these negative margins is comparatively lower when compared to both the baseline and BAU scenarios.

Conversely, in the SDP, crop products consistently yield positive gross margins across all agroecological zones and household types, and at higher levels than those seen in the baseline scenario. Furthermore, the magnitude of these positive gross margins increases progressively from small and marginal to larger and more affluent zones and household types, as illustrated in Figure 22.



**Figure 22: Annual mean gross margins for animal (top) and crop (bottom) products across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP) for marginal (MA), small (SM), semi-medium (SM) and medium (ME) household types.**



**Figure 23: Economic value of farm products with positive gross margins across four agroecological zones (Lower Gangetic Plains, LGP; Mid Gangetic Plains, MGP; Upper Gangetic Plains, UGP; Trans Gangetic Plains, TGP). A column with a value of 14, for example, indicates that there are 14 products in that economic-value category whose economic value is within the range of that economic value.**

## 1.6 Discussion

### 1.6.1 MAgPIE and CLEM model integration

Output from the India-scale MAgPIE modelling was used to inform both the direction of change of farming systems under future scenarios and also the magnitude of the change. In general terms this was an effective strategy to guide the development of the future scenarios. Some caveats around the effective downscaling of a national level model to the farm scale should be noted, although they do not discount the value of the joint modelling. For example, MAgPIE is a single-crop model (i.e. one crop is grown on each piece of land) whereas in all the farm scale simulations multiple crops were grown annually. It was possible to use the production variability for multiple crops produced in MAgPIE and combine these in the CLEM modelling.

The SDP future scenarios require significant change in farm management practice from the present day. They are not impossible scenarios, but they will be challenging to achieve, even should effective policy interventions and technical backstopping become widely available.

## 1.7 Conclusions

This exercise has demonstrated the feasibility of using a farm scale model, CLEM, to examine the farm productivity, labour requirements, economic productivity and gross margins of the animal and crop components for a range of household types across the Indian IGP. Using output from the national scale model, MAgPIE, was an effective method of determining boundary conditions for farm scale modelling.

Under current farming conditions it costs farms to rear animals and these costs are offset economically by the crop products produced on farms. There may be additional reasons (e.g. cultural, religious, etc) for households to raise livestock. Labour requirements, productivity and income all increase with increasing

household wealth, both within each agroecological zone from marginal to medium households and across agroecological zones from the LGP to the TGP. Under a BAU future farming is likely to get more challenging and less profitable, while under an SDP future farming remains an attractive option for rural youth, and an effective means of ensuring national food security.

## 1.8 References

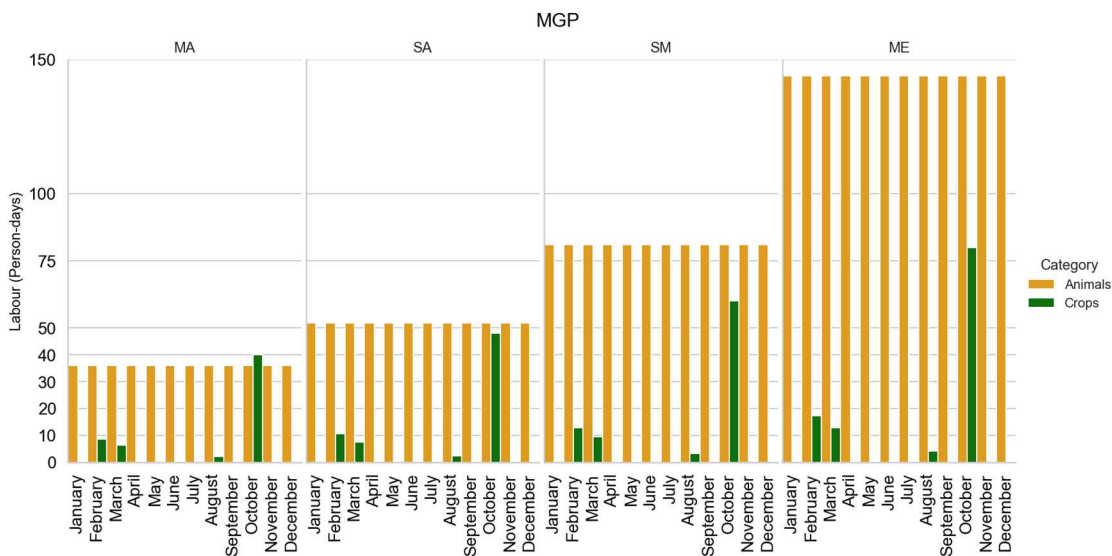
Ericksen, P., Thornton, P., Notenbaert, A., Cramer, L., Jones, P., Herrero, M., 2011. Mapping Hotspots of Climate Change and Food Insecurity in the Global Tropics. CCAFS Report no. 5. Available online at. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark. [www.ccafs.cgiar.org](http://www.ccafs.cgiar.org).

Gol, 2019. Categorization of Farmers into Five Agricultural Size Classes. Indian government website, accessed in February 2022 <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1562687>

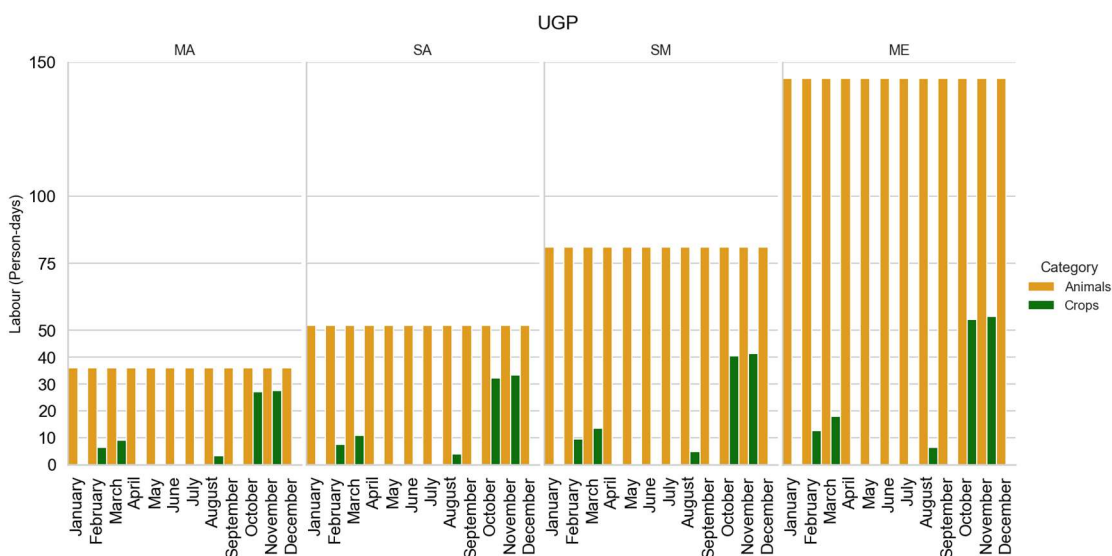
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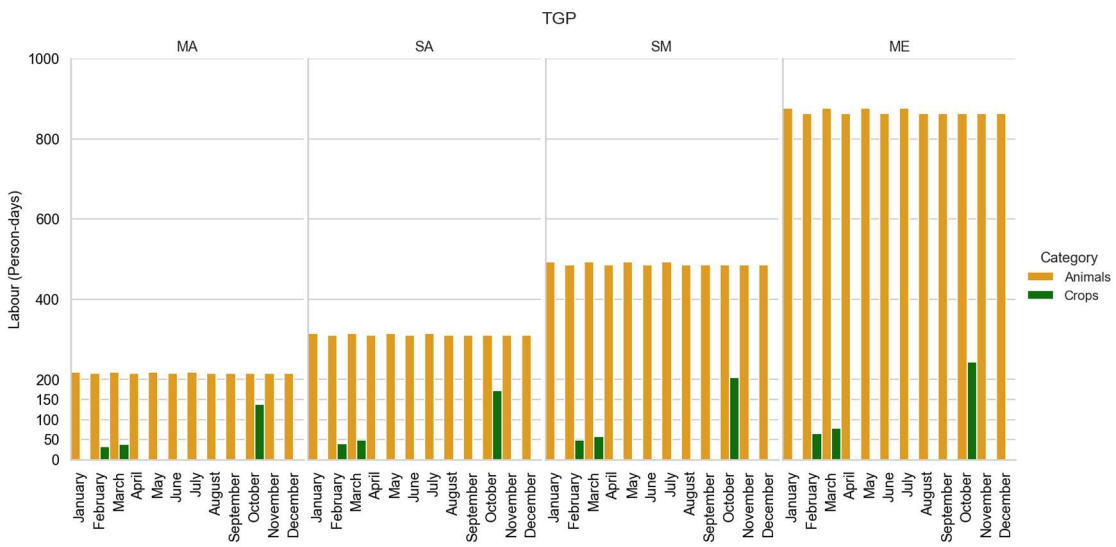
## 1.9 Appendix I: Baseline Annual labour variability in the MGP, UGP and TGP agroecological zones



Monthly labour requirements for animals and crops in the Mid Gangetic Plains (MGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.

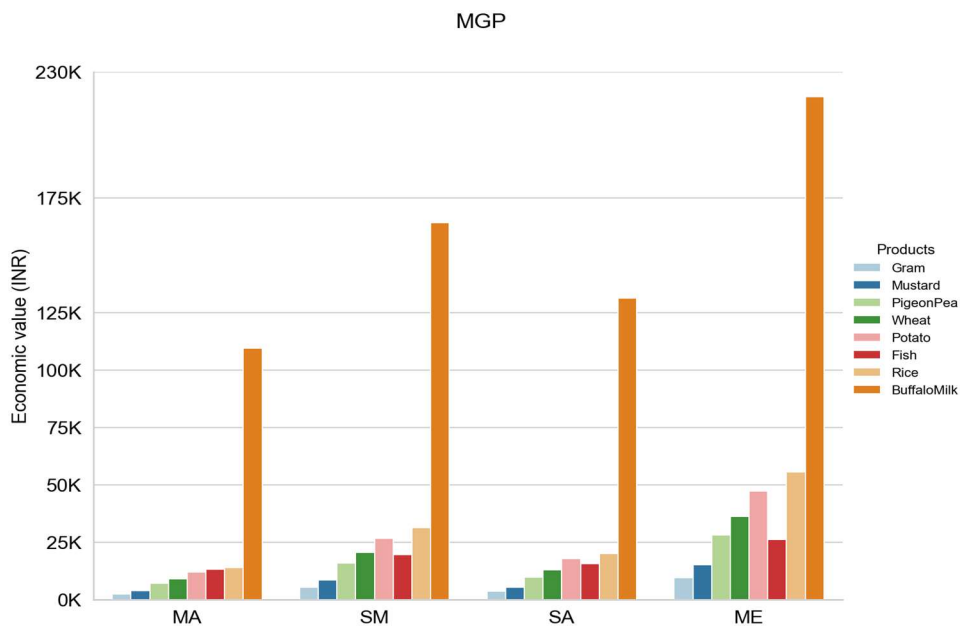


Monthly labour requirements for animals and crops in the Upper Gangetic Plains (UGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.

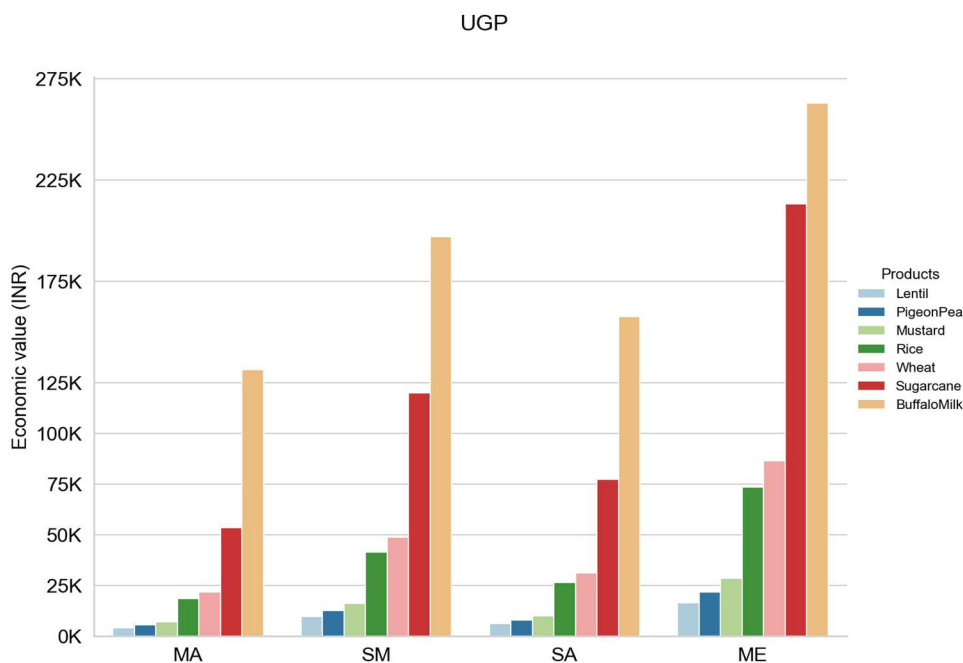


**Monthly labour requirements for animals and crops in the Trans Gangetic Plains (TGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types. Note that the Y-axis is an order of magnitude larger than that for the LGP, MGP and UGP graphs.**

## 1.10 Appendix II: Baseline economic value of farm products in the MGP, UGP and TGP agroecological zones

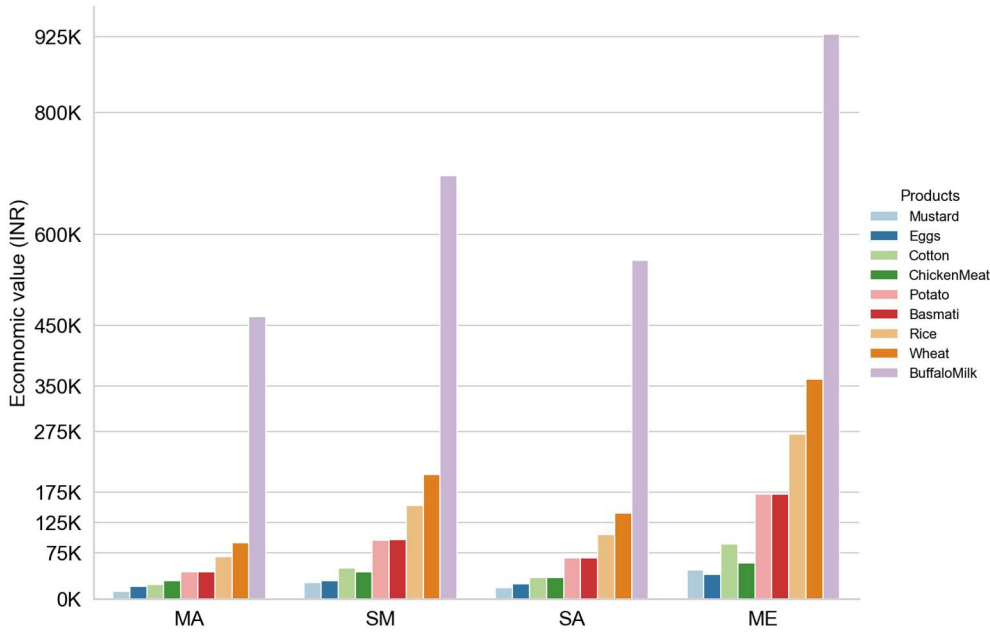


**Economic value of farm products in the Mid Gangetic Plains (MGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**



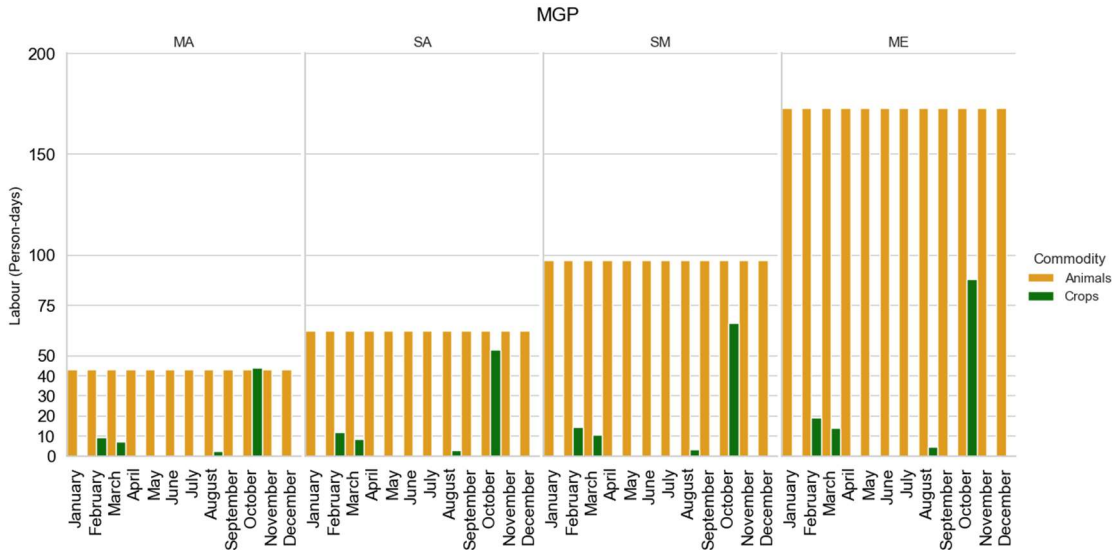
**Economic value of farm products in the Upper Gangetic Plains (UGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**

## TGP

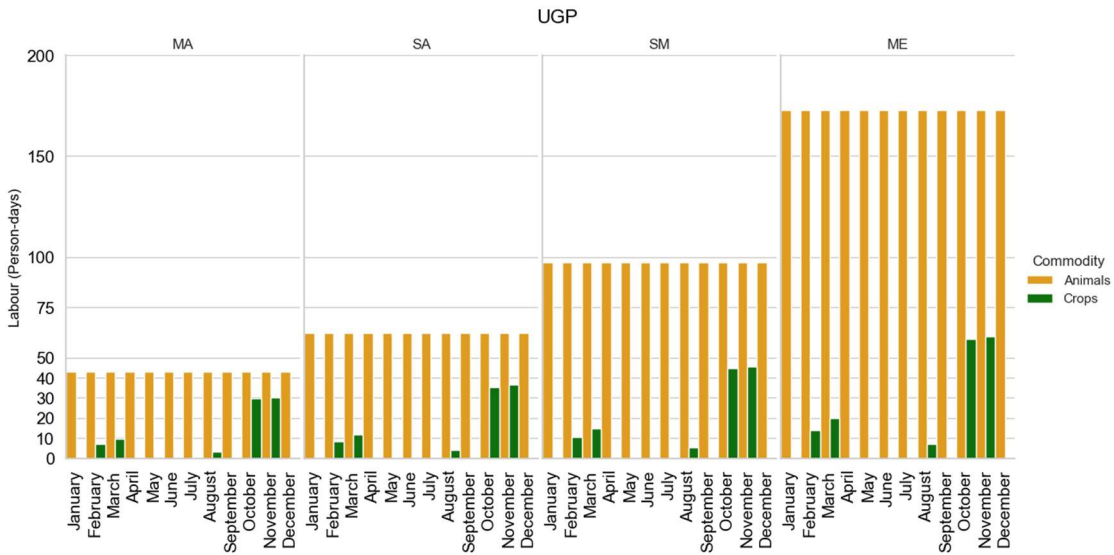


Economic value of farm products in the Trans Gangetic Plains (TGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.

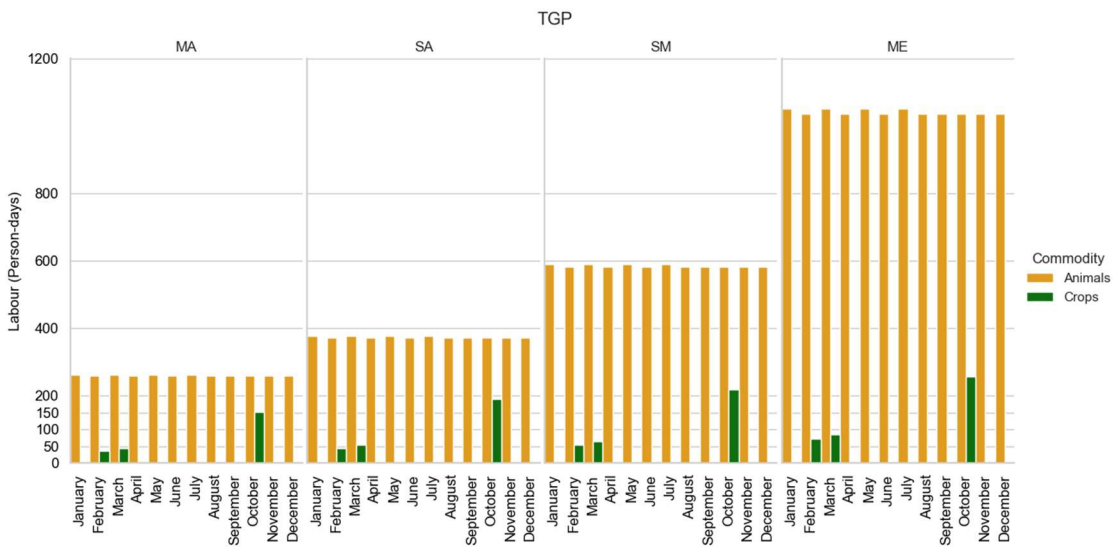
## 1.11 Appendix III: BAU annual labour variability in the MGP, UGP and TGP agroecological zones



Monthly labour requirements for animals and crops in the Mid Gangetic Plains (MGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.

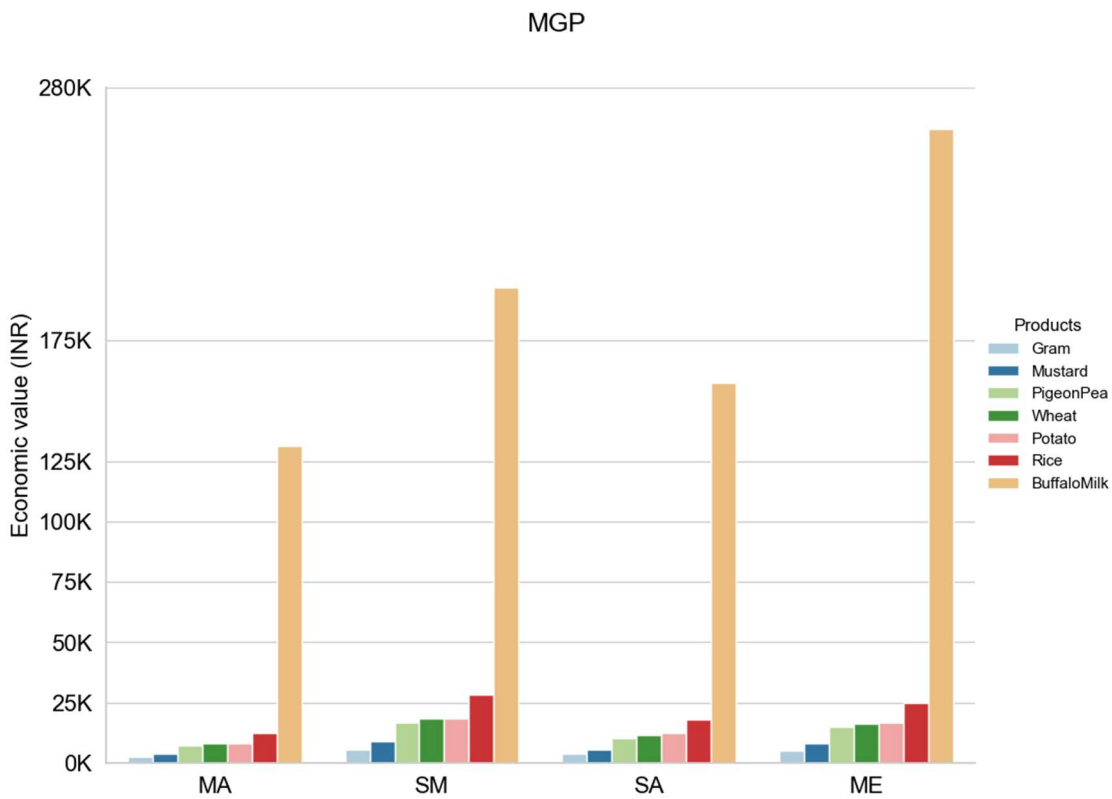


**Monthly labour requirements for animals and crops in the Upper Gangetic Plains (UGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**

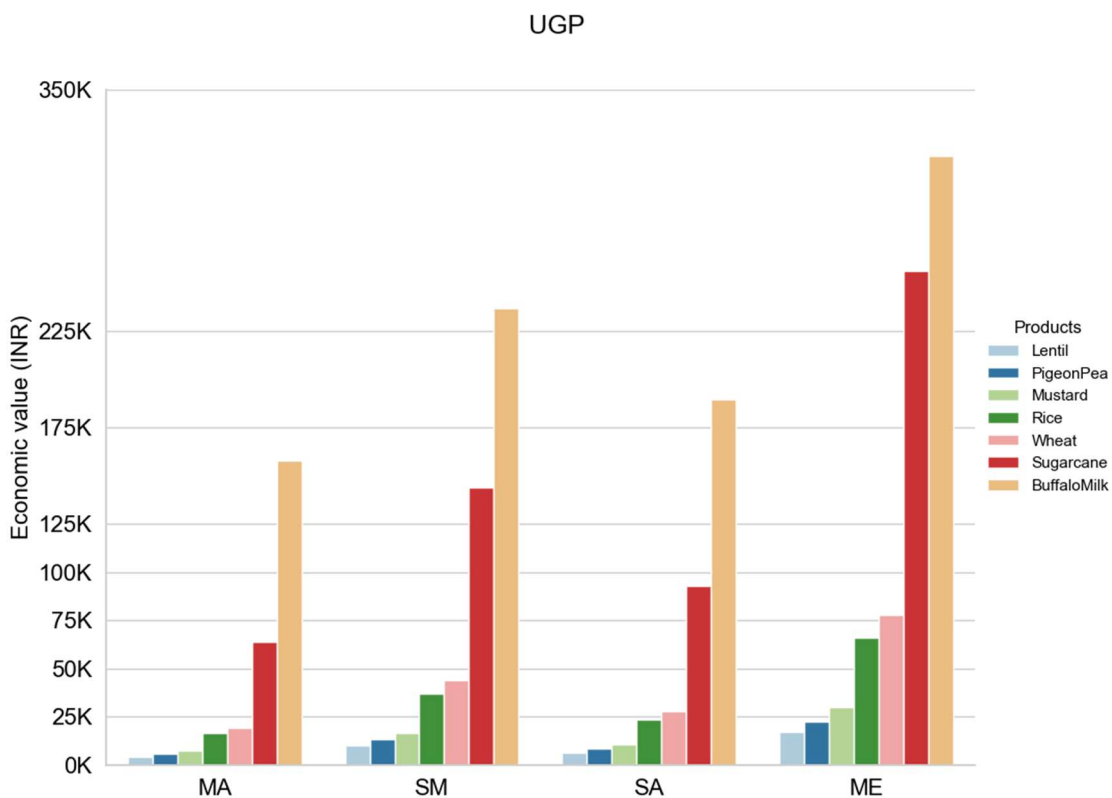


**Monthly labour requirements for animals and crops in the Trans Gangetic Plains (TGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types. Note that the Y-axis is an order of magnitude larger than that for the LGP, MGP and UGP graphs.**

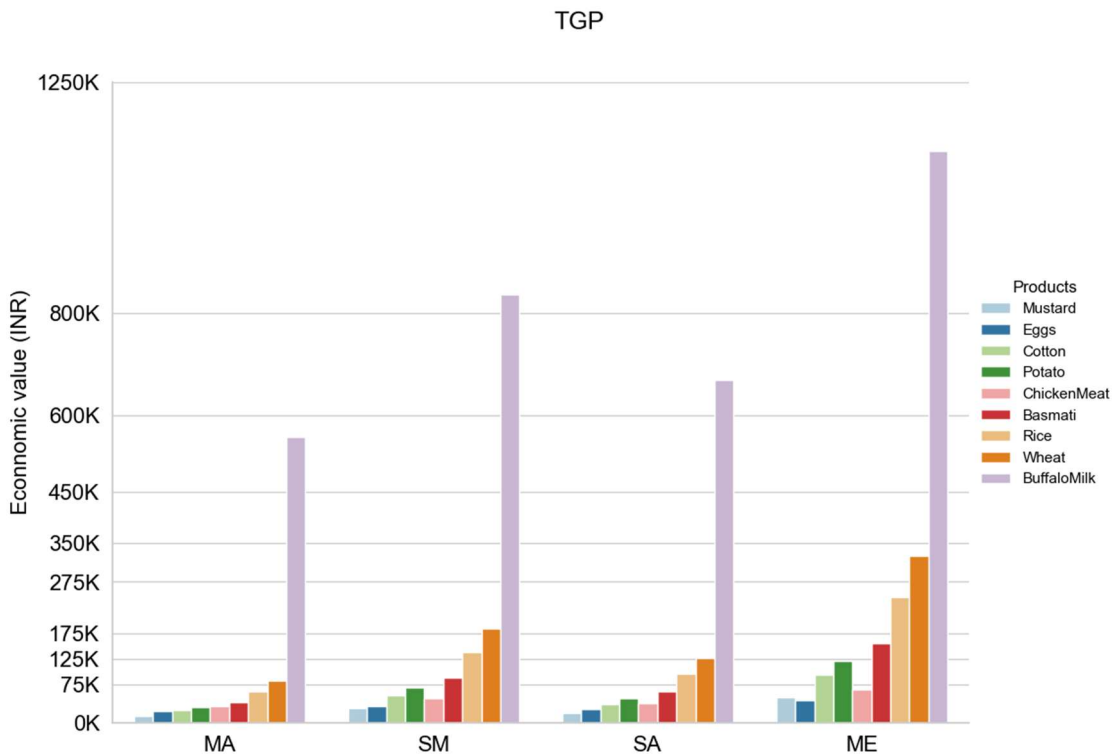
## 1.12 Appendix IV: BAU economic value of farm products in the MGP, UGP and TGP agroecological zones



Economic value of farm products in the Mid Gangetic Plains (MGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.

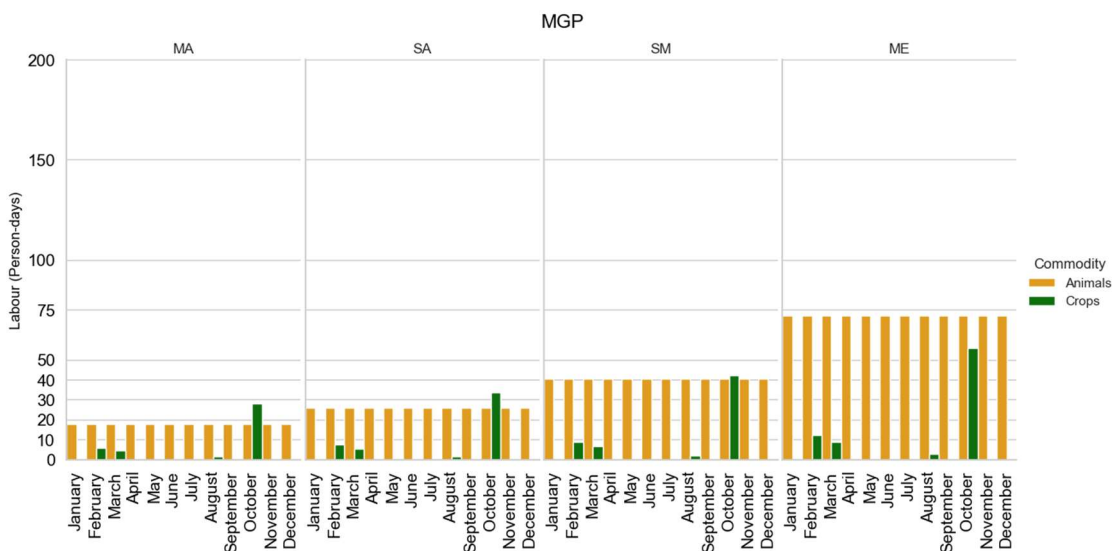


**Economic value of farm products in the Upper Gangetic Plains (UGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**

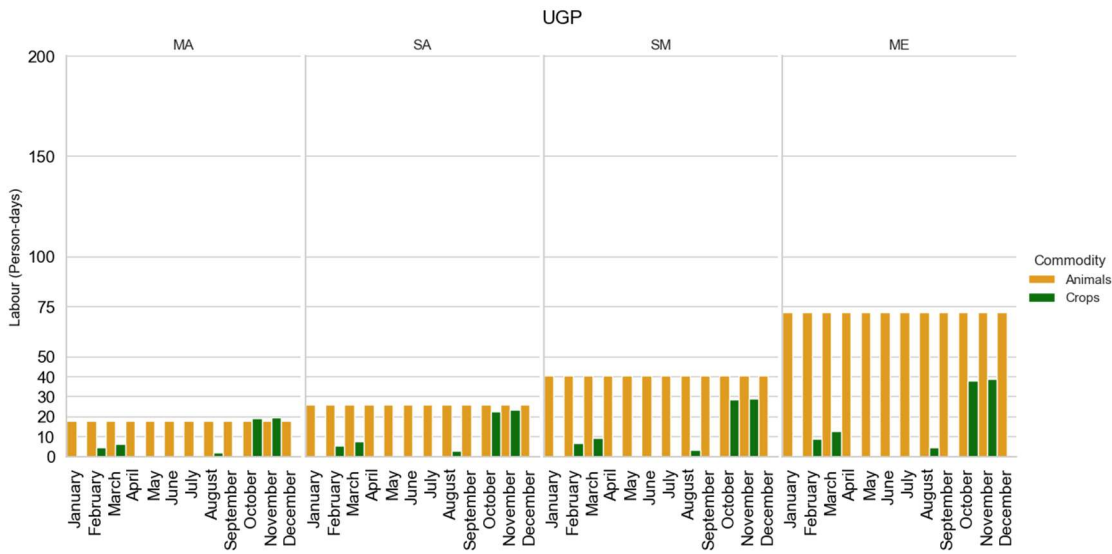


**Economic value of farm products in the Trans Gangetic Plains (TGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**

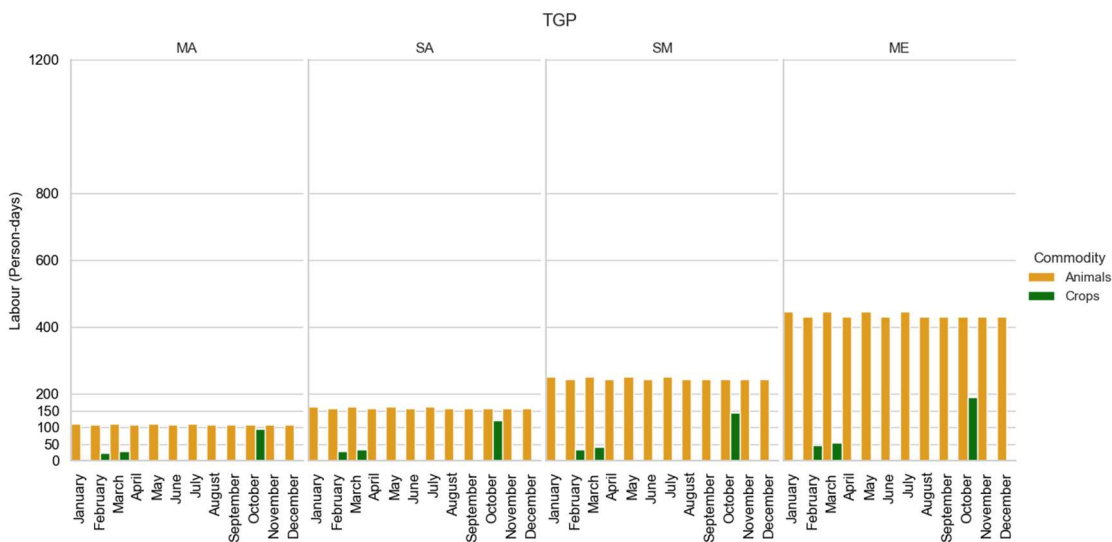
### 1.13 Appendix V: SDP annual labour variability in the MGP, UGP and TGP agroecological zones for



**Monthly labour requirements for animals and crops in the Mid Gangetic Plains (MGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**



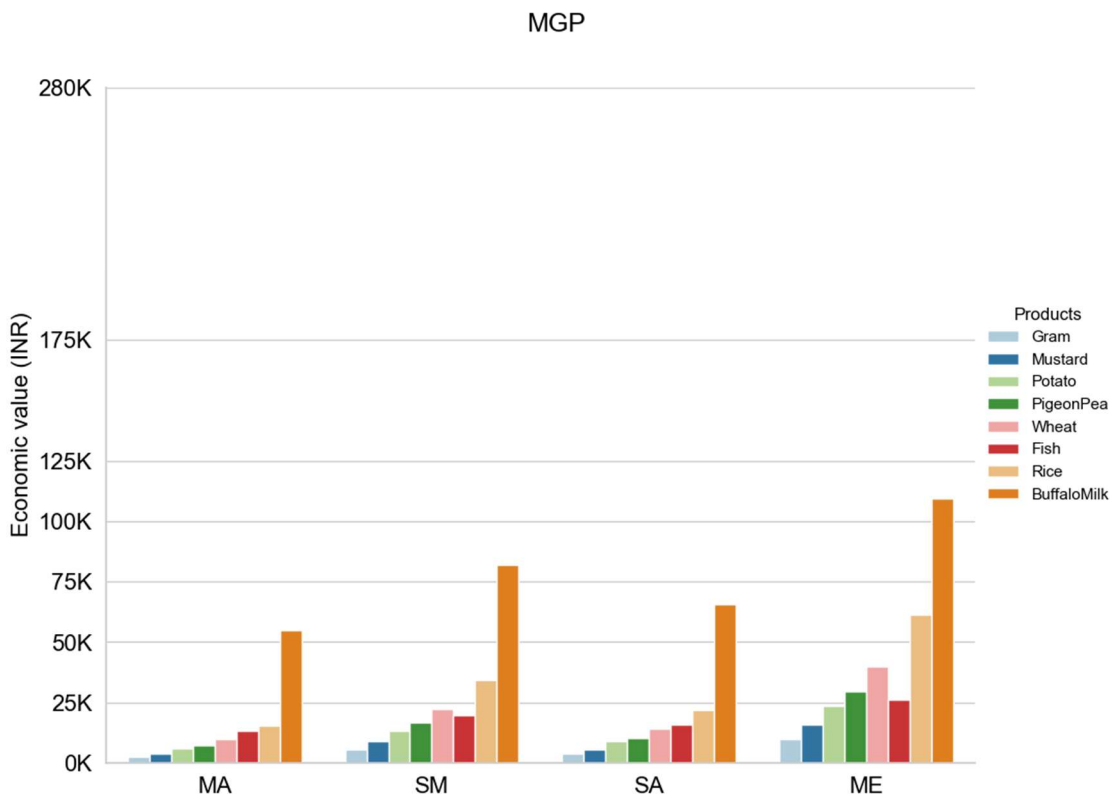
Monthly labour requirements for animals and crops in the Upper Gangetic Plains (UGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.



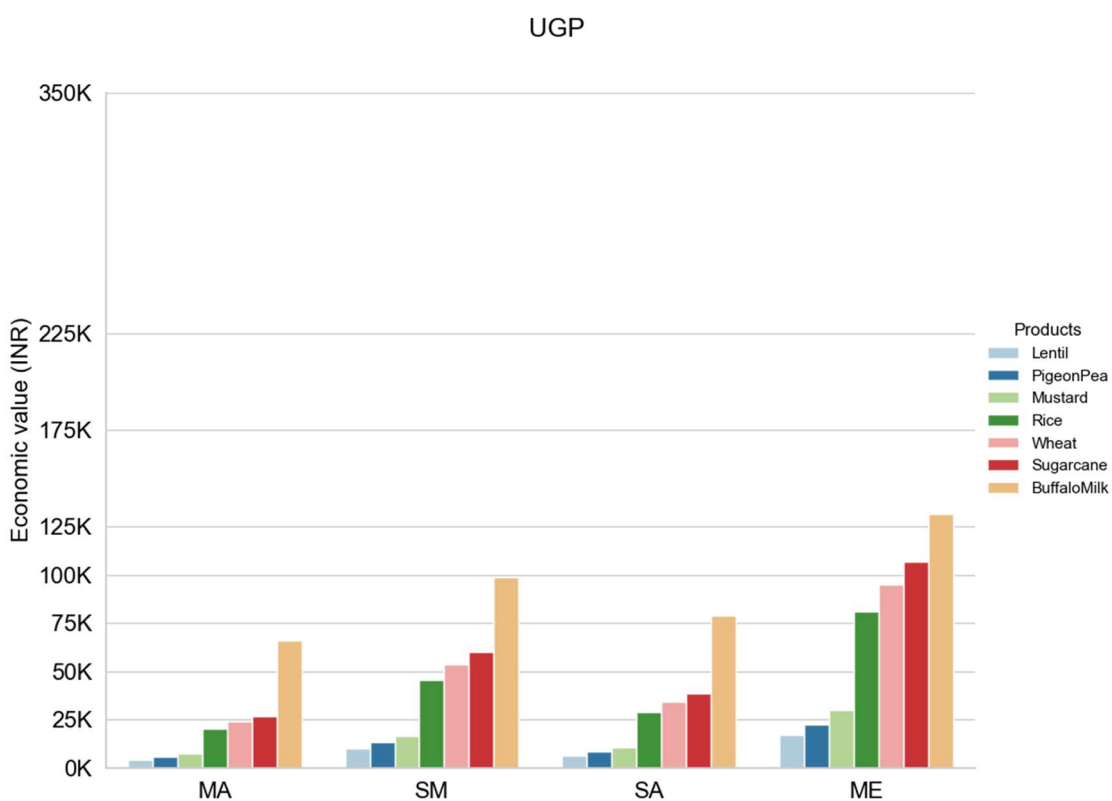
Monthly labour requirements for animals and crops in the Trans Gangetic Plains (TGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types. Note that the Y-axis is an order of magnitude larger than that for the LGP, MGP and UGP graphs.



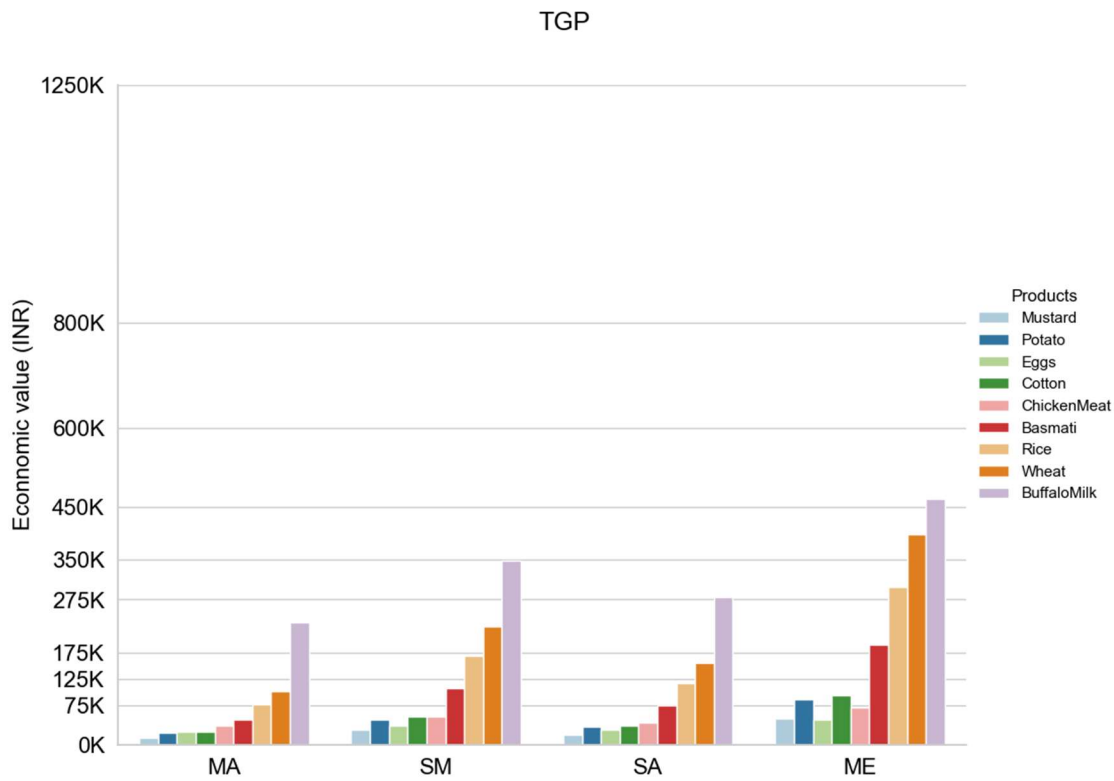
## 1.14 Appendix VI: SDP economic value of farm products in the MGP, UGP and TGP agroecological zones



**Economic value of farm products in the Mid Gangetic Plains (MGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**



**Economic value of farm products in the Upper Gangetic Plains (UGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**



**Economic value of farm products in the Trans Gangetic Plains (TGP) agroecological zone for marginal (MA), small (SA), semi-medium (SM) and medium (ME) household types.**

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