

The 100% Organic Agriculture Policy in Bhutan – A gift or a curse?

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An earlier version of this conference paper was presented at the 19th Annual Conference on Global Economic Analysis, Washington DC, USA, June 2016

Acknowledgements:

The authors would like to thank Chencho Dukpa, Scott McDonald, Johannes Mössinger and Harvey Bradford as well as the participants at the 19th Global Economic Analysis conference in Washington DC, USA and the 2016 DAAD Summer School at the College of Natural Resources in Lobesa, Bhutan for their helpful comments and feedback.

Keywords:

Organic agriculture conversion; CGE; Yield gap; Field operations; Agroecological zones; Food self-sufficiency

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Abstract

Organic agriculture is considered an environment-friendly agricultural system and thus one strategy to make agriculture more sustainable. Bhutan has embraced the ambitious goal of becoming the world's first 100% organic nation by 2020. Effects of such large-scale conversions at the national level have been rarely studied, particularly in cases of genuine pursued policies. Analysing recent on-farm data in Bhutan we find organic crop yields on average to be 19.1% lower than conventional yields. Based on these yield gaps, we assess the effects of a 100% conversion policy employing an economy-wide model with detailed representation of Bhutan's agricultural sector incorporating agroecological zones, crop nutrients and field operations. Despite Bhutan's low dependency on conventional inputs, we find significant welfare losses, particularly for non-agricultural households. The yield gap is the main driver for a strong decline in agricultural output (13.5%). Food supply is largely compensated by increased food imports, which results in a weakening of the country's cereal self-sufficiency (9.4%). Nitrogen availability declines strongly (22.2%), underlining the need of improved soil-fertility practices e.g. biological fixation of nitrogen. Our results show no benefits for rural labour markets as agricultural wages decrease (1.3%), despite higher labour intensity. The study further highlights policy implications and areas of future research.

1. Introduction

There is an uncontested need to reduce the environmental impacts of agriculture and that converting from a conventional to an organic agricultural system is viewed as one strategy to meet this need (NRC, 2010). A key challenge is, however, not to compromise the supply of food and biomass. Current studies on large-scale conversions vigorously debate the existence and size of yield gaps between conventional and organic agriculture (e.g. Ponisio *et al.*, 2015) and the question whether 100% organic agriculture (OA) can feed a growing world population (Badgley *et al.*, 2007; Connor, 2008). So far, little research has been conducted on the economy-wide impacts of large-scale conversions to OA at national scale. This might be due to the lack of genuinely formulated policy objectives, which aim at converting the entire agricultural sector at larger scale. Bhutan has received remarkable international attention following its announcement to become the world's first 100% organic nation by 2020 (Paul, 2015).

OA is a holistic agricultural system that strictly relies on natural inputs and promotes practices including the maintenance of soil fertility, conservation of biodiversity and animal welfare (IFOAM, 2014). The usage of agrochemicals (i.e. any chemical fertilizer and pesticides) and genetically modified crops is prohibited. In animal husbandry, the use of artificial growth hormones is banned and antibiotics are only allowed in exceptional cases. In 2012, 37% of Bhutan's farmers used agrochemicals on about 19% of arable land (MoAF, 2013). Given its low reliance on agrochemicals, there is the notion that the country is destined for 100% OA (Tashi, 2015). OA also fits well with Bhutan's Gross National Happiness (GNH) philosophy, within which environmental conservation is one of the four pillars (GNHC, 2013).

Due to the absence of agrochemical inputs, access to nutrients for plant growth is limited and the occurrence of pests and diseases is more difficult to manage in OA, resulting in lower yields than in conventional agriculture (CA). This is well documented for developed countries

(Ponisio *et al.*, 2015), but there is very limited research on OA's relative productivity in developing countries generally, and in Bhutan specifically. Our study contributes to this research gap by estimating organic-to-conventional yield ratios of 16 annual and perennial crops using on-farm data from ca. 6,200 Bhutanese farmers.

The second step of our analysis and more important contribution of this study is to assess the economy-wide impacts of Bhutan's 100% organic policy. Given agriculture's critical role for the country's economy, employing about 50% of labour force in 2012 (NSB and ADB, 2012), significant effects of such an unprecedented national conversion policy on household welfare and food self-sufficiency are to be expected. Furthermore, we are specifically interested in how the conversion affects agricultural output, land supply and availability of crop nutrients, which is why our model includes a detailed representation of the agricultural sector.

2. Study context

2.1. Simulation model-based studies on socio-economic impacts of OA conversion

Socio-economic impacts of OA conversion are often analysed on the farm level using mathematical-programming based models (Acs *et al.*, 2007). These studies allow for a detailed depiction of organic and conventional agricultural systems, particularly regarding the role of crop rotation, nutrient cycles and seasonal labour requirements. However, the system boundary of farm-level models is too limited to study an OA conversion at large-scale levels, which affects the entire economy.

Studies investigating the impacts of large-scale conversion scenarios have not referred to a genuinely pursued policy objective, but are rather based on stylized thought-experiments. Using their estimates of organic yields, Badgley *et al.* (2007) projected that under a global 100% OA scenario food supply would be sufficient to feed the world's population in their reference year 2001. Pretty *et al.* (2005) quantified the reduction in external costs of agricultural production if

the UK's agricultural sector would entirely switch to organic. Both Badgley *et al.* (2007) and Pretty *et al.* (2005) used static, linear models that did not account for market mechanisms. Jacobsen and Frandsen (1999) simulated a 100% conversion in Denmark with a comparative-static, single-country CGE model. They found a range of aggregate decline of agricultural production from 10% to 34%, depending on yield level and feed import assumptions. Using the global partial equilibrium model IMPACT, Halberg *et al.* (2006) show that global food availability would not be severely reduced by a large-scale OA conversion. However, the authors assume an increase in yields after switching to OA in low-input regions (i.e. developing countries) and their model does not capture economy-wide effects.

2.2. OA-CA yield differences

Ponisio *et al.* (2015) conducted the most recent and comprehensive meta-study analysing 1071 organic-to-conventional yield comparisons from 115 studies covering 52 crop species. They find organic yields to be 19.2% lower than conventional yields and in contrast to Seufert *et al.* (2012), could not determine a significant difference between yield gaps in developed versus developing countries. As there is a scarcity of empirical data from developing countries, only 14% of comparisons in the dataset of Ponisio *et al.* originate from developing countries, the magnitude of yield difference in developing countries arguably remains a controversy. Ponti *et al.* (2012) and Seufert *et al.* (2012) found average organic-to-conventional yield ratios of 0.84 and 0.57 for developing countries, while an earlier meta-study by Badgley *et al.* (2007) even reported a ratio as high as 1.7. Critics highlight that ratios above one for developing countries are potentially biased, as in some cases low-input conventional systems are compared with optimized OA systems (Connor, 2008). On the other hand, the very low ratio reported by Seufert *et al.* (2012) is partially explained by atypically high conventional yields (Reganold, 2012). In Bhutan, the only study on organic-to-conventional yield ratios found no significant differences for paddy within three different agroecological zones (Tashi and Wangchuk, 2015).

In contrast, other studies found evidence that more intensive conventional agriculture through (higher) application of agrochemicals would increase yields in the current low-input farming system in Bhutan (Chettri *et al.*, 2003; Dema *et al.*, 2012).

2.3. Availability of crop nutrients

A key challenge of OA is the supply and availability of crop nutrients, particularly nitrogen. As the organic fertilizers (e.g. compost, animal manure) permitted in OA provide a lower nutrient density and a slower nutrient release compared to synthetic fertilizers, nutrient availability in OA often does not match plant needs (Tilman *et al.*, 2002). Animal manure is the main source of nutrients in Bhutan, however, availability is decreasing due to shortages of agricultural labour (Dema *et al.*, 2012). Manure is either manually spread on fields or distributed by animals while being tethered on the fields. Using a top-down approach, it is estimated that about 193,830 tons of manure were consumed in 2012 (Feuerbacher *et al.*, 2017). According to long-term experiments, the average dry matter manure applied in Bhutan has a nutrient content of 1.6% nitrogen (N), 0.8% phosphorus (P) and 2.9% potassium (K) (Chettri *et al.*, 2003). Total nutrients consumed in Bhutan can be separated by source as shown in Figure 1.

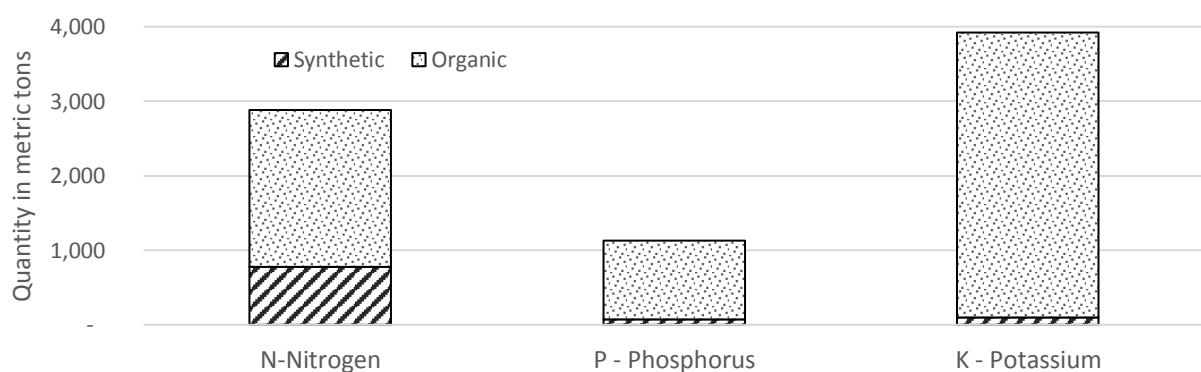


Figure 1 – Estimated source of nutrients applied as fertilizer in Bhutan in 2012 (own calculations based on FAO, 2015; MoAF, 2009 & 2013b)

P and K from synthetic sources make up only a small share (7% and 3%, respectively). Synthetic fertilizer is much more important as a source of N, comprising 27% of total consumed N. On average over all arable land, just 12.5 kg of synthetic NPK/hectare was applied in 2012. This ratio is higher (23.1 kg/hectare) when only the conventionally cultivated land is considered.

It is argued that at large-scale levels synthetic N could be replaced by OA soil fertility management practices, such as green manuring (Badgley *et al.*, 2007). In the context of Bhutan, Chettri *et al.* (2003) showed that the use of green manures is an option to achieve recommended nutrient levels for the cultivation of rice (but not for wheat). Particularly in Bhutan's temperate zones, green manuring would require cropped area that previously was utilized for cultivation of food crops, thus resulting in a reduction of food supply. Further, as green manuring is labour intensive, its potential in Bhutan is limited due to labour shortages. As of today, crop rotations with green manures or grain legumes are only "practiced in isolated pockets of [Bhutan] where water and labour are available" (Tashi, 2015, p. 105). Animal manure mixed with crop residues (i.e. farmyard manure) is the most important organic fertilizer in Bhutan. Given the limited role of other organic fertilizers (e.g. composts made from food and crop waste and leaf litter) and the lack of data, we only consider manure as a source of organic nutrients in the following analysis.

2.4. Labour intensity

OA is generally known to be more labour intensive than CA, but this factor receives little attention in the literature. Vaguely, it is assumed that rural dwellers would benefit from an organic conversion as OA would provide more employment (Badgley *et al.*, 2007; Reganold and Wachter, 2016). However, in Bhutan labour shortages are a long observed farming constraint, which is caused by various factors including human-wildlife conflict, rural-urban

migration and land fragmentation. In 2012, more than 60% of Bhutan's farmers mentioned labour shortage as a problem (MoAF, 2013), particularly in those months where labour is required for transplanting, weeding or harvesting (Yeshey *et al.*, 2013). Due to this, herbicides such as Butachlor (used for paddy), Metribuzin (potato) and Glyphosate (maize, paddy and potato) are increasingly applied by Bhutanese farmers (Yeshey and Bajgai, 2014; Tshewang *et al.*, 2016). Tashi and Wangchuk (2015) found that organic rice farmers in Bhutan have an 11% higher labour requirement, because more person-days per hectare are needed for weeding and applying farmyard manure. Labour availability could thus be a key challenge for a 100% OA conversion in Bhutan.

2.5. Policy background

The general concern for the environment is deeply anchored in Bhutan's policies, for instance by the constitutional mandate to maintain 60% forestry cover at all times (RGoB, 2008) or the pledge to stay a carbon neutral country (RGoB, 2010). Part of the 100% organic policy rationale is to promote Bhutan as an organic brand, which shall help to commercialize smallholder agriculture, alleviate poverty and add value to the tourism sector (Duba *et al.*, 2008). In order to become 100% organic, Bhutan's government intends to "phase out [the] use of harmful chemical fertilizers and pesticides" (RGoB, 2010, p. 29), which effectively resembles a ban on agrochemicals. There is no domestic agrochemical production in Bhutan. The import of agrochemicals is a government controlled monopoly and comprised just about 0.2% of total imports (in value terms) (FAO, 2012; MoF, 2013). Hence, the influence of interest groups lobbying for the use of agrochemicals is negligible and a ban on importing or producing agrochemicals could be relatively easy to implement. This ban would only affect cropping systems directly, as animal husbandry in Bhutan follows traditional practices with negligible use of non-compliant inputs such as artificial growth hormones.

The 100% OA objective was first announced in 2008 (Tashi, 2015), however, since then progress in achieving this goal has been rather slow. Since 2008, the consumption of synthetic fertilizers remained stable, while the use of pesticides experienced a strong positive trend increasing by an average growth rate of 11.8% (see figure S1 in the supplementary materials). In 2012, 13,943 hectares were cultivated under CA, i.e. 18.6% of total cultivated land (MoAF, 2013). The remaining 61,194 hectares were largely managed as “organic by default”, i.e. no organic certification but also no usage of agrochemicals. To date, only about 545 hectares of crop land (less than 1% of total arable land) are certified organic (NOP, 2016). However, the Royal Government of Bhutan (RGoB) does not necessarily tie achieving 100% OA to governmental certification, except for exports, which have to be certified organic (Neuhoff *et al.*, 2014).

Expert interviews with government representatives, researchers and farmers conducted between 2014 and 2016 yielded that Bhutan’s 100% organic policy is – contrary to the development in Europe or in the US - not driven by a bottom-up grassroots movement, but rather considered a top-down policy. In the same line, an early report noted: “farmers lack awareness on organic farming. They are even confused: why organic now when they have just learnt to practice conventional farming” (Duba *et al.*, 2008, p. 21). A more recent article states that it is not known “whether Bhutanese farmers are really in favour of converting to OA” (Neuhoff *et al.*, 2014, p. 219, 2014).

In 2003 a focal agency, the National Organic Program (NOP), was established within the Ministry of Agriculture and Forests (MoAF) that pursues the objective to provide appropriate OA technology and information (NOP, 2016). Research on organic farming is concentrated at one of the five national Renewable Natural Resources (RNR) research centres (Duba *et al.*, 2008). The RNR research policy formulated in 2011 only refers to organic farming once in 24 pages by stating to “give primacy to organically clean agriculture and minimize the role of

external inputs” (RGoB, 2011, p. 7). Given the challenge of converting to 100% organic, the current research capacity is still too limited and would need to be expanded significantly (Neuhoff *et al.*, 2014).

Bhutan, unlike many South Asian countries, has achieved a relatively high degree of food security as reflected by most nutrition indicators. Yet, stunting of children aged less than five and anaemia affecting women and children remain serious challenges (Atwood *et al.*, 2014). Besides impacting food security, the OA policy could conflict with the objective of increasing self-sufficiency in cereals – a key priority of Bhutan’s agricultural policy. Through investments in mechanization and irrigation schemes, domestic paddy production shall be increased by 26% until 2018 (GNHC, 2013). This would increase the degree in rice self-sufficiency from 57% to 67%. Bhutan’s food security is at the mercy of India, from where almost all rice imports originate. When India imposed export bans on rice and other essential food items during global food price spikes, Bhutan has been the only exempted trade partner (GoI, 2014). This dependency on India could jeopardize food security, as there are no border posts with China, Bhutan’s only alternative access to world markets via land. When government leaders of Bhutan and China informally met in 2012, India reacted by withdrawing subsidies for cooking gas and kerosene exports causing an unexpected flip in the 2013 elections in Bhutan (BBC, 2013). Against this background, increasing food self-sufficiency is a valid national priority and this study will assess how this policy objective is affected by a 100% organic conversion.

3. Data sources and methodology

To simulate the effects of a 100% organic policy in Bhutan we follow a two-step approach. In step one, we utilize available on-farm data to test for differences in productivity of OA and CA within each of Bhutan’s three agroecological zones (AEZs). In step two, we employ a single country Computable General Equilibrium (CGE) model to simulate the economy-wide impacts

of the 100% organic policy. CGE models are a wide-spread method to assess policies and exogenous shocks particularly in the field of agriculture and food policy (Urban *et al.*, 2016; Boulanger and Philippidis, 2015). Both steps are linked by updating the model's database, a 2012 social accounting matrix (SAM) of Bhutan, using the results of the yield difference estimation.

3.1. Data and estimation procedure of OA-CA yield differences

The underlying dataset for the analysis of yield differences is the Agricultural Sample Survey (ASS) 2012 that interviewed ca. 6,200 farmers about their crop output (MoAF, 2013). Crops are classified as conventionally produced if farmers used chemical fertilizers, pesticides or both on the crop area. The dataset is combined with altitude data on the sub-district (*gewog*) level to generate variables identifying the following three main AEZs. AEZ1 is the humid, sub-tropical zone at altitudes below 1,200 meters above sea level (masl). AEZ2 is the dry-subtropical AEZ in altitudes between 1,200 and 1,800 masl. AEZ3 is the temperate zone in altitudes above 1,800 masl.

Yield data, calculated by dividing production in kilograms by area in hectares, is cleaned by excluding the 1% and 99% percentile outliers within each crop and AEZ. Yield differences are calculated as an organic-to-conventional ratio per crop and AEZ level if at least 25 observations were available per cultivation system (OA or CA), otherwise the crop was excluded from the analysis. Fieller confidence-intervals are calculated for the yield ratios and significance levels are tested conducting the non-parametric¹ Wilcoxon rank-sum test on absolute yield levels. The results of this analysis are utilized to update the model database: In case the yield difference is found significant ($p\text{-value} < 5\%$), the cultivation system specific mean yields are used to compute total quantity produced per crop based on the distribution of land in the database

¹ A non-parametric procedure is applied as the Shapiro-Wilk W test revealed that the majority of crop yields neither follows a normal nor a lognormal distribution.

among cultivation systems. If yield differences are not significant, the mean of all observations per crop across both cultivation systems is employed.

3.2. Economy-wide model framework

3.2.1. Model database

The 2012 Social Accounting Matrix (SAM) for Bhutan determines the structure of economic institutions and agents and is documented in (Feuerbacher *et al.*, 2017). In order to fit the modelling structure of this study, the following two modifications are implemented:

Firstly, data from the ASS 2012 and the Bhutan Living Standard Survey 2012 (NSB and ADB, 2012) are used to disaggregate farm activities, factors and households according to the three AEZs. Crop-producing activities are further disaggregated according to cultivation systems (i.e. OA or CA), which results in cultivation system and AEZ specific input-output structures. Tashi and Wangchuk (2015) did not find any significant differences in the selling price of organic and conventional rice in Bhutan. Due to the lack of a market for officially certified organic products, this finding can be generalized for all domestically sold organic produce in Bhutan. Hence, while there is a differentiation between organic and conventional production, there is none between organic and conventional produce. In other words, both OA and CA activities produce perfectly substitutable goods.

Secondly, eight field operation activities (e.g. organic plant protection, conventional plant protection, etc.) are incorporated using available crop budget data. Each of them produce a corresponding field operation commodity that enters the crop producing activity as a production input. The field operation “Mechanical land preparation”, for instance, comprises ploughing and puddling of land using a powertiller requiring fuel, agricultural labour (*Family and hired labour*) and agricultural capital (*Powertiller*). The incorporation of field operations is a novel

feature in CGE modelling. It allows to explicitly model the trade-off between technological choices and directly links the labour requirement to each operation, rather than aggregating it

The final SAM consists of 118 accounts, of which the majority is related to the agricultural sector. There are 25 economic activities performed by farm households which produce 30 commodities. These farm activities include cultivation of crops, livestock husbandry, community forestry and various post-harvest activities. They either use family or hired labour, which is supplied by farm and landless households. Cultivated land is disaggregated into three types: irrigated land used for rice production, rainfed land and orchards, which is land used for permanent crops. Further production factors used by farm activities consist of two livestock accounts (cattle and other animals), pasture land, powertillers (used for land preparation) and an account including all remaining machinery. Some farm outputs such as crop residues, fodder, manure and draught animal services are used as intermediate inputs by other farm activities. Just as field operations, they are assumed to be non-tradables within Bhutan and thus are segmented according to AEZs. Further, all remaining agricultural factors are assumed to be immobile across AEZs.

In total there are 14 factor accounts, of which ten are agricultural factors used by farm activities and four factors are used by industry and service sectors. Formally employed labour is disaggregated into skilled and unskilled labour. Incorporated capital is differentiated by private and public capital, which represents income to private and public enterprises, respectively. The SAM further includes 12 household accounts, which are disaggregated according to factor ownership and residence in either rural or urban areas. A table listing all SAM accounts is provided in S2 of the online supplementary materials.

3.2.2. Behavioural relationships in the model

The CGE model adapted for this study is the single country, comparative-static STAGE2 model which is comprehensively described in McDonald and Thierfelder (2015). The agents in the model are production activities, households, incorporated enterprises, the government and the capital market. Household consumption follows a Linear Expenditure System derived from the maximization of a Stone-Geary utility function. This entails differentiation between subsistence and discretionary consumption. Following the Armington insight (1969), demand for domestically produced and imported commodities is imperfect and specified by a Constant Elasticity of Substitution (CES) function. Domestically produced commodities are supplied to the domestic and world market (i.e. exports) using Constant Elasticity of Transformation (CET) functions.

The standard production structure of STAGE2 consists of a three-level nest aggregating intermediate inputs and production factors, which is adopted for the model's non-agricultural activities. The light shaded nests in Figure 2 represent this standard structure, with the exception that the land aggregate being shifted from level L3.1 to L5.2. Generally, we assume that intermediate inputs and value added components are aggregated according to Leontief technology at L1. Intermediate inputs are also demanded in fixed shares (L2.1). Value added at L2.2 and factor aggregates below (L3.2 and 3.3) are aggregated using CES technology.

In case of agricultural activities, the Bhutan model used for this study extends the production structure by incorporating field operations, which are represented by the dark shaded nests in Figure 2. As only cropping activities use field operations and land, this part is empty for the remaining activities. Level L3.1 governs the activities' degree of intensification by aggregating area cultivated and fertilization. An important relationship is captured at the AreaCultivated nest L4.1, which is a Leontief composite of field operations and land. Assuming a fixed share

at L4.1 makes land only substitutable with fertilizer at level L3.1, which is reasonable, as increasing the cultivated area also increases the requirement for labour for land preparation, harvesting, etc. At L4.2 the operations chemical and organic fertilization are aggregated, which include both the fertilizer and the labour required to apply it. This is one exemplary technological trade-off represented in the structure, further trade-offs are the nests L6.1 (land preparation) and L6.2 (plant protection). These latter two are aggregated at fixed shares together with other operations at L5.1. Other operations includes all field operations which do not include any technological trade-off such as sowing, irrigation and harvesting.

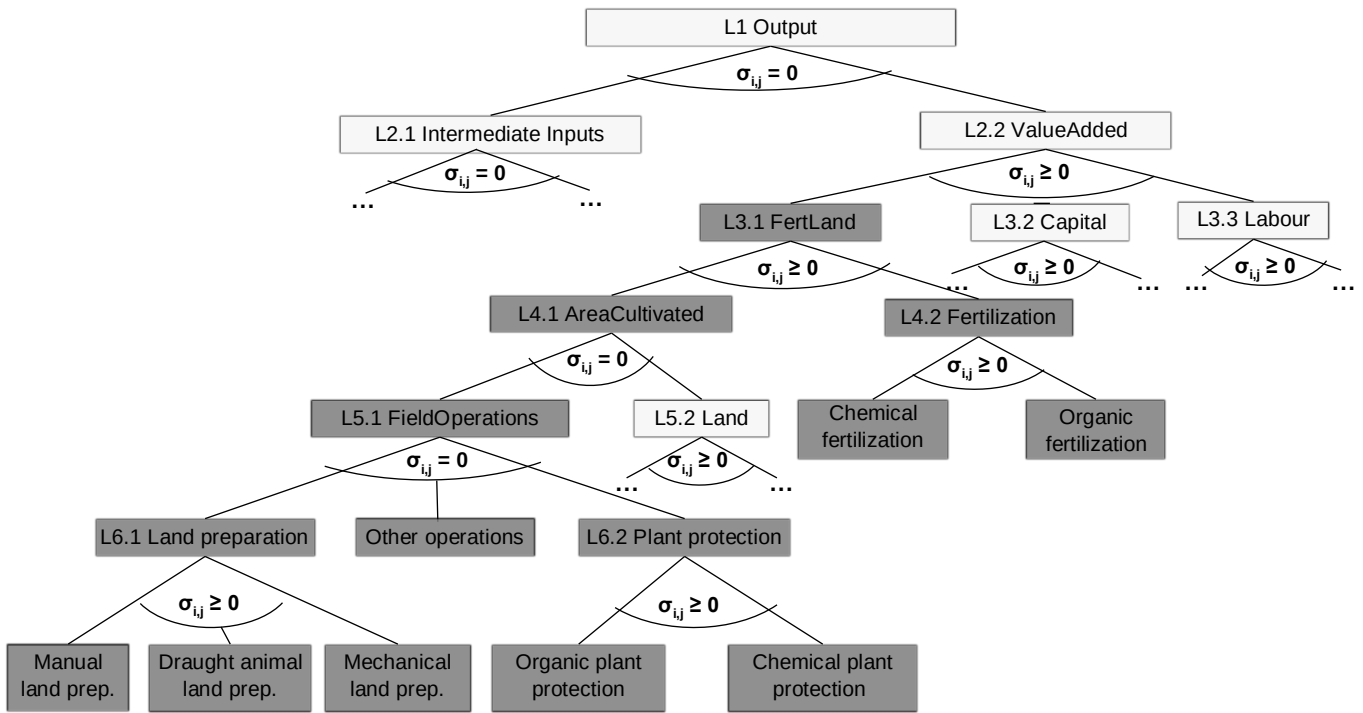


Figure 2 – Extended production structure of economic activities

In addition to the production structure, the model was extended to include margin for exports and to allow for flexible output of multi-product activities (e.g. cattle husbandry) using a CET specification. These extensions as well as the substitution elasticities across the various CES nests in Figure 2 are documented in S3 of the online supplementary materials.

3.2.3. Model closures

Our model assumes that Bhutan is a small country, i.e. world market prices are fixed. The external balance is flexible and in turn the exchange rate is fixed. This reflects Bhutan's current currency regime of a one-to-one peg of the Bhutanese Ngultrum with the Indian Rupee.² The consumer price index is set as the model's numeraire. The model is investment-driven (investment is fixed as a share of final demand) with equiproportionately varying saving rates for households and enterprises. Government consumption and savings are fixed in quantity terms, and the government account is balanced by relative changes in the income tax rate.

Capital supply is constant and assumed to be immobile and activity specific as we consider a short term adjustment horizon. Skilled and unskilled labour are perfectly mobile across activities. Agricultural labour, both family and hired labour, are segmented according to AEZs, and thus only mobile within the activities of the same AEZ. The three land-types (irrigated-land, rainfed-land and orchard) are set immobile across AEZs and cultivation systems, establishing the entry point of the shock of converting to organic agriculture. Unlike the other factors, the model closure for land accounts for unemployment, as a significant share of total arable land was left fallow in the base period. The land supply regime is explained within the next section.

3.2.4. Modelling approach

To achieve Bhutan's 100% organic policy, a likely real world policy instrument would be a ban on the use of agrochemicals. In a CGE model, such a policy is typically mimicked using a prohibitive tax (e.g. import or sales tax) which increases prices such that economic agents are incentivized to entirely substitute the use of the taxed good (Boulanger *et al.*, 2016). This

² India is by far Bhutan's most important trade partner, accounting for more than 78% of imports and 94% of Bhutan's exports in 2012 MoF (2013).

approach has the disadvantage that a very high distortion of input prices would be needed in order to achieve a scenario close to 100% conversion. Therefore, a novel approach is applied in this study, modelling the phase-out of CA as an exogenous conversion of conventional to organic land within each AEZ and land type.

$$CVT0_{on} = FS0_{cn} * shrcvs * mapland_{cn,on} \quad (1)$$

Equation 1 describes the converted quantity of conventional to organic land $CVT0_{on}$, which is the base supply of conventional land $FS0_{cn}$ multiplied by the share of conversion $shrcvs$ and the diagonal matrix $mapland_{cn,on}$ to map organic (*on*) and conventional (*cn*) land-types according to AEZ and land type. Due to technical reasons, $shrcvs$ is limited to 99.99% to simulate Bhutan's 100% organic policy.

Organic activities may not absorb all converted land and the portion of unutilized converted land is captured by the variable $CVTIDLE_{on}$. The land price is assumed constant (i.e. supply at perfect elasticity) if the total supply of land within each AEZ and land-type is equal or smaller than base supply. However, land prices increase according to an upward sloping land supply curve once fallow land from the base period is put under cultivation, which then represents a land expansion within a specific AEZ and land-type.

$$WF_{on} = \begin{cases} WF0_{on}, & \text{if } FLW_{on} \geq FLW0_{on} \text{ or } CVTIDLE_{on} > 0 \\ \left(\frac{FS0_{on} + (FLW0_{on} - FLW_{on})}{shfs_{on}} \right)^{\frac{1}{elaf_{on}}}, & \text{if } FLW_{on} < FLW0_{on} \text{ and } CVTIDLE_{on} \leq 0 \end{cases} \quad (2)$$

Equation 2 formally describes the binary mechanism that determines the factor price for organic land-types (*on*), WF_{on} . $FS0_{on}$ is the organic land supply in the base period, $FLW0_{on}$ is the base quantity of fallow land, FLW_{on} is a variable for fallow land, $shfs_{on}$ is a calibrated shift parameter, and $elaf_{on}$ is the supply elasticity which is set to 0.1. There are no specific land

supply estimates for Bhutan, but the selected elasticity fits well within the range of land supply elasticities applied by van Meijl *et al.* (2006).

$$FS_{on} = FS0_{on} + (FLW0_{on} - FLW_{on}) + (CVT0_{on} - CVIDLE_{on}) \quad (3)$$

Following equation 3, adding the changes in fallow land and the net quantity of converted land to organic land supply in the base period, one arrives at the new organic land supply FS_{on} .

$$FS_{on} - (CVT0_{on} - CVIDLE_{on}) = FS0_{on} + (FLW0_{on} - FLW_{on}) = shfs_{on} * WF_{on}^{elaf_{on}},$$

if $FS_{on} > FS0_{on}$ (4)

Equation 4 shows that after rearranging equation 3, the bottom part of equation 2 is a reformulation of the general land supply function.

4. Results

4.1. Yield differences between OA and CA

The yield difference estimation shows that conventional yields are mostly higher than organic yields (i.e. yield ratios below 1). Differences are statistically significant for 17 out of 25 yield comparisons at the 5% level, with 13 comparisons being statistically significant at the 0.1% level (Figure 3). The prevalence of CA is highest in AEZ3, with 46.5% of cultivated area under CA. These shares are much lower in AEZ2 (12.1%) and AEZ1 (1.4%), which explains the lower number of yield comparisons in these AEZs.

Referring to the simple average organic-to-conventional-ratio, average OA yields are 19.1% lower than in CA being very close to the recently estimated global mean ratios of 0.80 and 0.81 by Ponti *et al.* (2012) and Ponisio *et al.* (2015). The estimated ratios for paddy, which are of particular importance given Bhutan's focus on rice self-sufficiency, are only statistically significant within AEZ2 and AEZ3, where 70.2% of paddy is produced. For paddy in AEZ1, the confidence interval is below the unitary ratio, but the Wilcoxon ranksum test does not yield

a significant difference. Hence, in AEZ1 we assume no paddy yield differences between CA and OA. Table 1 provides an overview of shares of conventional production across crops and regions after adjusting for significance in yield differences. Besides for major crops (i.e. paddy, maize and potato), crops are aggregated in the SAM, which is why yield differences of minor crops (e.g. cabbage) are not directly traceable in the model.

The relevance of crop yield differences for the economy-wide simulations in step two depends on the share produced by CA and a crop's relative weight within the agricultural sector. Table 1 shows that according to both criteria, paddy, maize and potato have the highest shares produced by CA and are also among the most important crops accounting for 48% of total crop output. In AEZ2 and AEZ3, these crops also have large and significant yield gaps (c.f. Figure 3). In contrast, the conventional production of other crops (e.g. other cereals and vegetables) is of very small magnitude or does not even exist (e.g. spices).

Table 1 – Percentage shares of crop output value as represented in model database

Crop Name / Region	% -share of CA in output value per crop and region				% -share of crop output in output value of total crops
	AEZ1	AEZ2	AEZ3	National	
Paddy	3.3%	29.2%	61.1%	30.4%	22.0%
Maize	1.3%	12.3%	63.8%	22.0%	12.8%
Other Cereals (includes legumes and oilseeds)	0.0%	3.3%	8.3%	4.3%	7.2%
Vegetables	0.0%	8.9%	29.6%	18.6%	15.1%
Potato	0.0%	16.5%	88.5%	77.1%	12.9%
Spices	0.0%	0.0%	0.0%	0.0%	9.1%
Fruits	2.6%	1.9%	63.1%	15.0%	20.9%
Total crops	1.7%	13.0%	57.1%	25.7%	100.0%

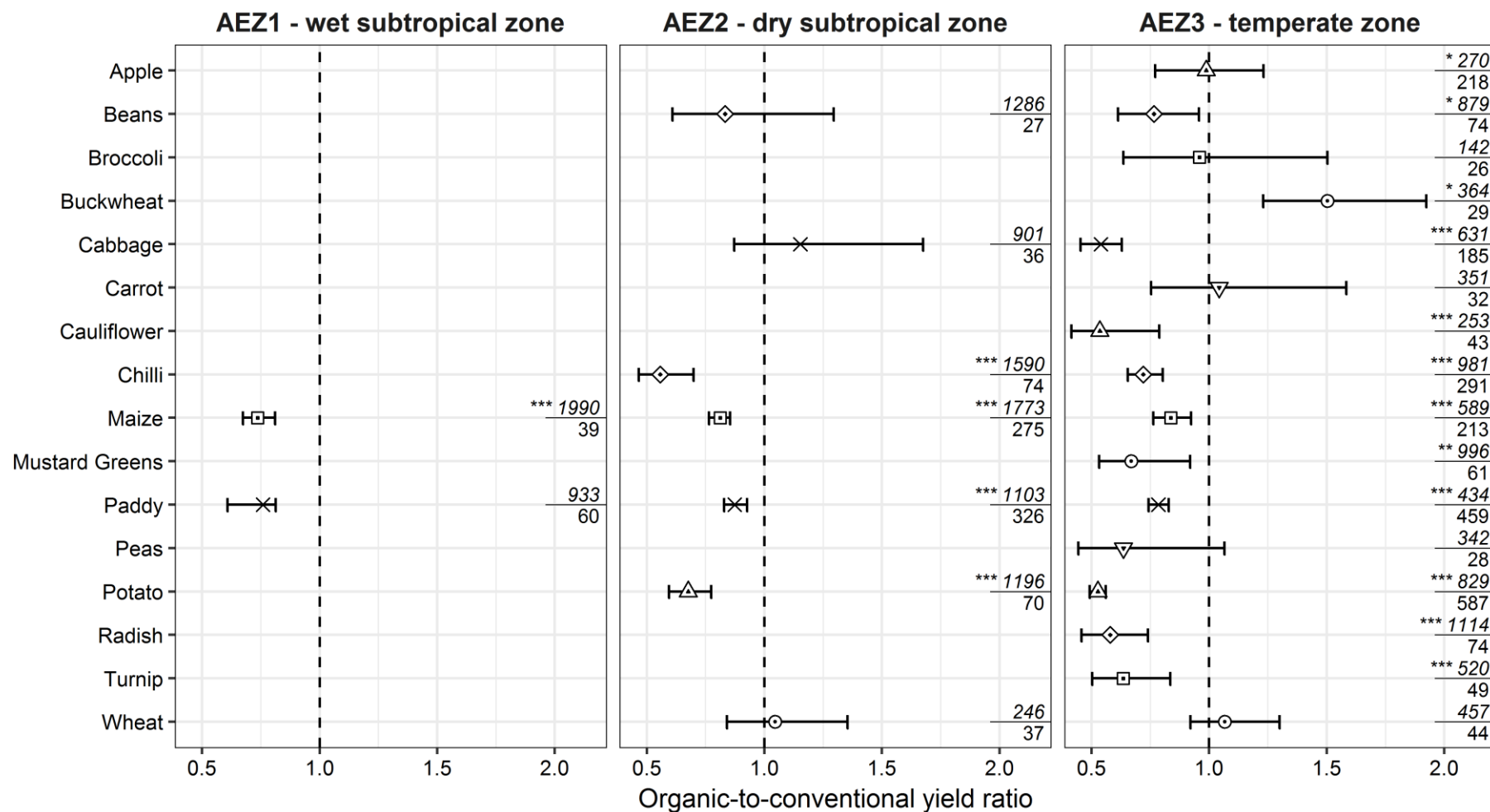


Figure 3 - Organic-to-conventional yield ratios for 16 crops across agroecological-zones in Bhutan (based on data from MoAF; 2013); Panel right-hand sides show significance level of Wilcoxon rank-sum test and the fraction shows the number of organic (numerator) and conventional (denominator) observations.

4.2. Model results: Economy-wide changes of the 100% OA policy

4.2.1. Macro-level changes

The large-scale exogenous conversion of conventional land constitutes a negative factor endowment shock due to generally higher yields within CA. In the base, all conventional land (13,943 hectares) accounted for 18.6% of total cultivated land, but comprised a disproportionately higher share of total land returns (24.3%).

Consequently, the 100% organic policy results in decreasing overall economic activity (Figure 4). Households experience a loss in purchasing power as factor income declines and food prices surge (see section 5.2.3) and as a consequence, household consumption shrinks (-5.2%). Investments as a fixed share of aggregate demand decrease (-2.3%). Fixing the government demand in quantity terms results in constant government expenditure in real terms. In line with falling household demand imports also decrease, however, to a lower extent (2.6%). Exports increase (2.6%) as decreasing non-agricultural factor prices (Table 3) raise the competitiveness of export industries. Foreign savings decline strongly (10.7%) as a result of a lower current account deficit. Overall, the model results suggest that Bhutan's economy would experience a drop in real GDP of 1.1% and a drop in total domestic absorption by 2.9%.

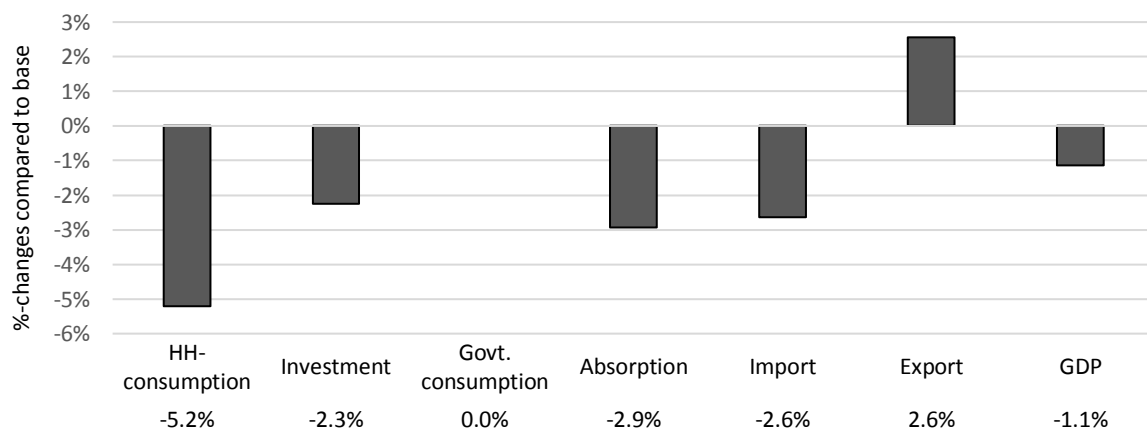


Figure 4 - %-changes of macro indicators in real terms after simulating a 100% organic policy

4.2.2. Changes in factor markets

An overview of the converted land per land type and AEZ is provided in Table 2. The largest share of conversion occurs in the AEZ3, while the shock affects only a small share of cultivated land in AEZ2 and particularly AEZ1, where most agriculture is “organic by default”. After the conversion, total cultivated land increases slightly by 0.5%. Changes in total land supply differ across AEZs. In AEZ1 and AEZ2, fallow land is cultivated in addition to reallocated conventional land. In contrast, in AEZ3 not all previous conventional land is cultivated. The OA policy affects land-types very differently. Total irrigated-land and orchards decline (-5.9% and -3.4%), while the cultivation of total rainfed-land increases (3.3%).

Table 2 - Reallocation of conventional land and change in cultivated organic land

AEZ	Land Type	Organic land (ha) - FSO_{on}	Converted conventional land (ha) $CVT0_{on}$	Change in cultivated organic land after conversion (ha) $(FLW0_{on} - FLW_{on}) + (CVT0_{on} - CVIDLE_{on})$	%-chg. in total cultivated land
AEZ1	Irrigated-land	5,446	186	262	1.4%
	Rainfed-land	14,779	92	736	4.3%
	Orchard	5,314	86	114	0.5%
	Sub-Total	25,539	364	1,112	2.9%
AEZ2	Irrigated-land	5,045	1,831	1,548	-4.1%
	Rainfed-land	16,599	1,408	2,166	4.2%
	Orchard	2,181	36	47	0.5%
	Sub-Total	23,824	3,275	3,761	1.8%
AEZ3	Irrigated-land	1,869	2,301	1,532	-18.5%
	Rainfed-land	9,141	7,512	7,743	1.4%
	Orchard	820	533	186	-25.6%
	Sub-Total	11,830	10,347	9,460	-4.0%
National	Irrigated-land	12,360	4,318	3,342	-5.9%
	Rainfed-land	40,519	9,012	10,645	3.3%
	Orchard	8,315	655	347	-3.4%
	Total	61,194	13,986	14,333	0.5%

The declining supply of total irrigated-land is directly linked to the decreasing attractiveness of paddy. This is particularly the case in AEZ2 and AEZ3, where organic yields are significantly lower and a large share of output has previously been produced by CA. In contrast to irrigated-

land, farmers can cultivate a range of crops on rainfed-land and orchards, allowing them to specialize on those crops for which they have the highest productivity under the given conditions. Demand for rainfed-land is thus increasing in all AEZ.

Table 3 shows the changes in factor prices. Due to the inelastic land supply curve, land prices increase strongly once the perfectly elastic part of the land supply curve has been exploited. This is particularly the case for rainfed-land across all AEZs. Agricultural wages decline due to lower yields and thus lower productivity despite higher labour intensity within cropping activities. Aggregate labour absorbed by cropping activities in AEZ1 and AEZ2 increases by 4.8% and 5.8%, respectively, while in AEZ3 it drops by 4.7%, resulting in an aggregate increase by 2.3%. This additional agricultural labour is released by post-harvest and off-farm activities, either because of falling output prices reflecting lower demand for their final outputs (e.g. forestry and weaving of textiles) or because the availability of necessary inputs has declined (e.g. milling of cereals).

Table 3 - %-changes in factor prices after simulating a 100% organic policy

	AEZ1	AEZ2	AEZ3	National
Agricultural production factors				
Irrigated-land	13.7%	0.0%	0.0%	4.9%
Rainfed-land	51.4%	54.6%	26.7%	43.7%
Orchard	4.2%	3.8%	0.0%	3.8%
Pasture land	3.5%	4.6%	2.0%	3.3%
Family-farm-labour	-0.3%	-0.2%	-3.3%	-1.3%
Hired-farm-labour	-0.8%	-1.4%	-3.2%	-1.9%
Powertiller	7.3%	7.5%	-11.0%	-1.3%
Cattle	3.5%	4.6%	2.0%	3.3%
Other animals	-1.7%	-1.7%	-0.5%	-1.5%
Other machinery	-	-	-	-8.3%
Non-agricultural production factors				
Skilled-labour	-	-	-	-4.5%
Unskilled-labour	-	-	-	-5.2%
Private-capital (factor-income)	-	-	-	-4.3%
Public-capital (factor-income)	-	-	-	-0.3%

The overall reduction in household demand results in decreasing non-agricultural output, which has negative consequences for non-agricultural labour and capital. Since capital is set as immobile across sectors, its productivity endogenously varies across activities within the model. To interpret capital returns at an aggregate level, we report the change in factor income from capital which includes productivity adjustments.

4.2.3. Changes in agricultural output

Aggregate crop output declines by 13.5% in quantity terms resulting in a strong increase of crop prices (Figure 5). In quantity terms, the reduced output in paddy and potato explains the largest part (54.1%) of the contraction in crop output. Strong reductions in output are also observable for other cereals, spices and fruits, these crops have, however, lower shares in total production. Income elasticities play a role for the modest drop in maize production (-2.6%): maize is an extremely inelastic cereal in Bhutan and the income elasticity is just above zero. Due to these consumer preferences, the effect of the overall declining income is comparatively small for maize.

In many cases, reductions in output are absorbed by trade. The mechanism by which output reduction is absorbed by either or both increased imports or decreased exports is dependent on the initial trade linkage measured as a percentage of base supply. In the case of flour, i.e. processed other cereals, the import and export share is 94.1% and 78.7%, respectively. As other cereals become more expensive, output of flour is reduced strongly, while supply is almost unaffected. This is possible, because the decline in exports (-47.2%) and the increase in imports of flour (0.1%) cancel out the strong reduction in output (-42.8%). Being easily substituted by changes in trade, the supply of flour is thus very elastic. The same mechanism also explains the reductions in supply of rice, where imports increase by 14.9%.

In quantity terms, crop imports increase by 17.9%, of which 81.0% is explained by increasing imports of potatoes (92.7%) and vegetables (48.4%). Considering all food imports, the strong increase of milled rice imports (14.9%) represents in absolute terms the largest increase of any food item. Total crop exports experience a significant drop (28.0%), of which 58.6% is due to the strong reduction in potato exports.

Purchaser prices and output of edible livestock products decrease due to lower household demand (Figure 6), but also because of higher demand for complementary non-edible livestock output, i.e. manure and draught power. As the stock of animals is fixed exogenously, the supply of manure is inelastic. Consequently, following the conversion manure prices increase strongly across AEZ (13.9% to 21.4%). An increase in manure supply can only be achieved by increasing the recovery rate of manure droppings (e.g. by changes in animal husbandry from extensive pasture systems to indoor stable system). This is reflected in the model, by allowing a low substitution elasticity between cattle and labour in the production structure and by using a CET specification to govern the output composition, which allows for higher output shares of manure and draught power while decreasing output of edible livestock products. Livestock product imports decrease as purchaser prices drop and total domestic production including edible and non-edible products slightly increases.

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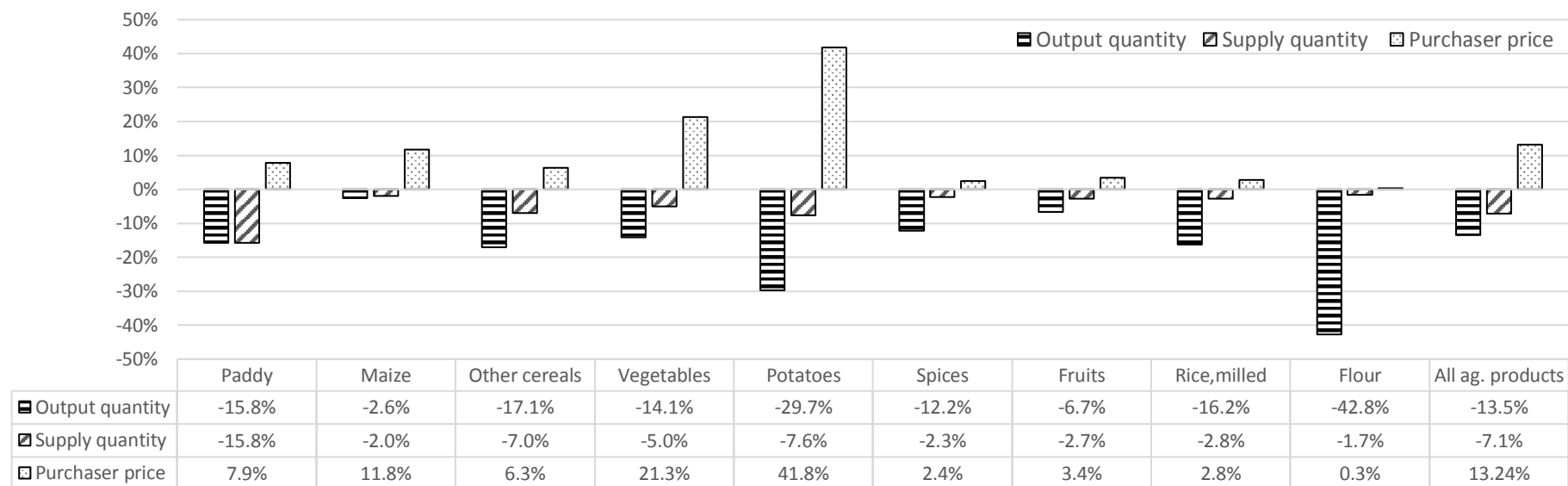


Figure 5 – %-changes in crop output, supply and purchaser prices after simulating a 100% organic policy

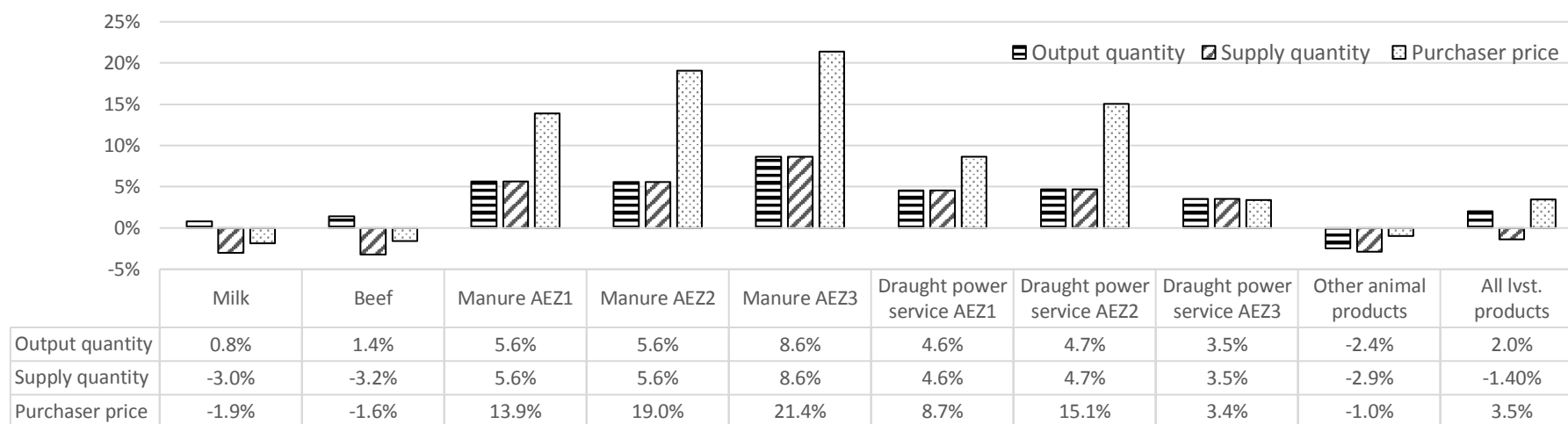


Figure 6 - %-changes in livestock product output, supply and purchaser prices after simulating a 100% organic policy

4.2.4. Changes in agricultural inputs

A 99.99% conversion results in an almost 100% reduction of agrochemical usage (Table 4), resulting in strongly increasing demand for organic plant protection and organic fertilization. The effects are most pronounced for AEZ3 where the share of converted conventional land is highest. Due to a slight increase of total land supply in AEZ1 and AEZ2 total demand for field operations increases. In AEZ3, where total cultivated land decreases, demand declines for mechanical-land-preparation, manual-land-preparation and other-operations.

Table 4 - %-changes of field operation quantity

	AEZ1	AEZ2	AEZ3
Mechanical-land-preparation	0.14%	0.15%	-0.20%
Draught-animal-land-preparation	4.56%	4.66%	3.55%
Manual-land-preparation	41.51%	74.69%	-4.55%
Organic-fertilization	5.67%	5.58%	8.70%
Chemical-fertilization	-99.98%	-99.98%	-99.99%
Other-operations	3.91%	5.54%	-8.49%
Organic-plant-protection	9.63%	23.92%	94.24%
Chemical-plant-protection	-99.99%	-99.99%	-99.99%

The intensity of fertilizer use decreases. While there is a slight land expansion, the aggregate supply of the nutrients N, P and K declines by 6.3% from 105.6 to 98.9 kg/hectare (Figure 7). In contrast to manure, most applied synthetic fertilizers have a NPK composition with high shares of N. Consequently, overall N availability is reduced significantly (22.2%), but the increase in manure supply (6.9%) results in stable availability of P (-0.2%) and a slight increase in K (3.4%) reflecting the relatively high content of P and K in manure.

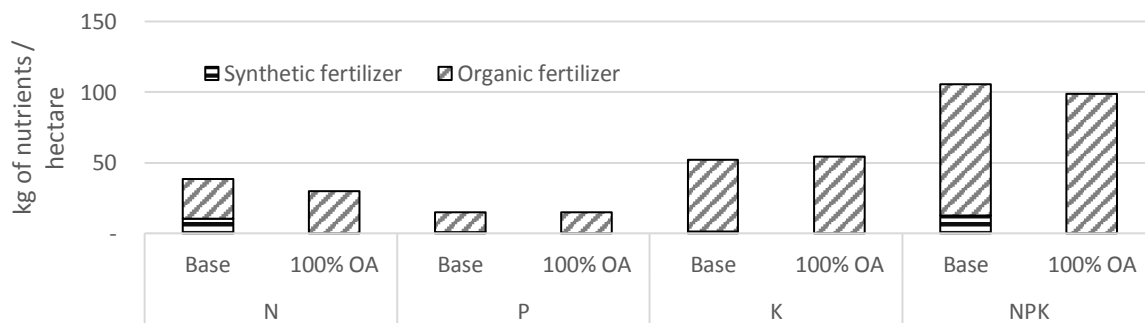


Figure 7 - Nutrient consumption per hectare before and after simulating a 100% organic policy

4.2.5. Changes in food security and welfare

Following a 100% organic conversion policy, national food self-sufficiency³ declines by 5.3% from previously 85.1% to 80.6%. Cereal self-sufficiency is reduced at an even higher relative rate (9.4%) from 61.8% to 55.9%. The decline in cereal self-sufficiency is largely driven by the substantial fall in paddy output (15.8%) and the increase in rice imports (14.9%). Converting to 100% OA thus directly conflicts with the government's objective to increase food self-sufficiency.

Welfare measured as the share of equivalent variation in base income and in USD per capita is decreasing for all households, except for agricultural households in AEZ1 (Figure 8). The average Bhutanese bears a welfare loss of 49.50 USD or 4.10% in terms of base income. In AEZ3, where most of the agricultural output is reduced, agricultural households experience a strong relative decline in welfare (6.7%). This is not only explained by declining agricultural wages, but also by a strong decline in cultivated irrigated-land (18.5%) resulting in lower factor income. Agricultural households in AEZ1 and AEZ2 experience the lowest relative welfare loss of all households besides the one reliant on transfers. Except for transfer dependent households, non-agricultural households suffer the highest absolute welfare loss in terms of equivalent variation per capita. At the aggregate level, agricultural households both experience lower welfare losses in relative (2.7%) and absolute (21.55 USD per capita) terms compared to non-agricultural households (4.7% and 74.42 USD per capita).

³ Self-sufficiency is computed by dividing the value of domestic production by the sum of the values of domestic production and imports minus exports using constant prices of the base period.

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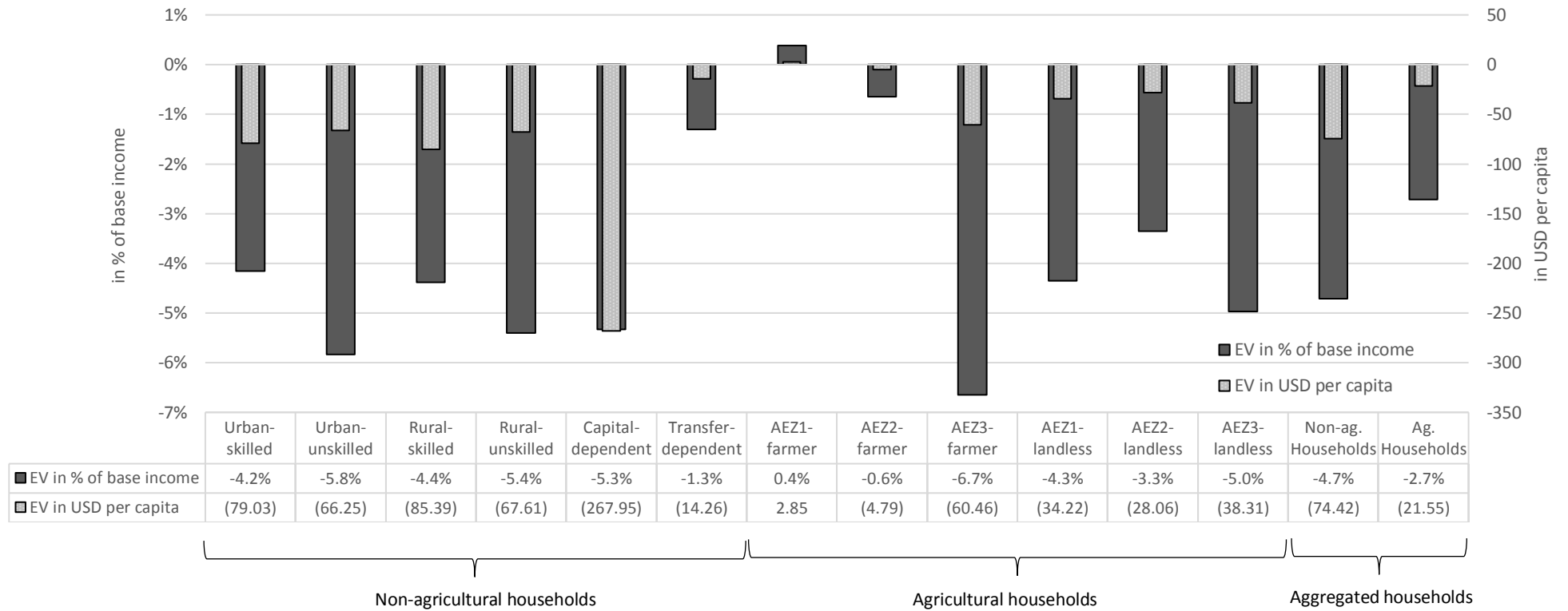


Figure 8 - Welfare effects of the organic conversion policy measured as equivalent variation (EV) in % of base income at left-hand side and in USD per capita at the right-hand side.

5. Discussion

The average organic-to-conventional yield ratio of 0.81 shows that there is a significant yield gap between OA and CA in Bhutan. Our results are contrary to Tashi and Wangchuk (2015) in this aspect. Applying ANOVA models on 2012 and 2013 rice grain yield data they could not find significant yield differences for any year and in any of Bhutan's AEZs. This difference in results cannot be explained by the year of measurement or the choice of statistical estimation procedure. Applying the same procedure (ANOVA) on our 2012 dataset, we even find the yield difference of paddy in AEZ1 to be statistically significant (p-value of 0.0000).

The underlying dataset has limitations regarding the coverage of all relevant variables that might influence yields. For instance, no information is included as to whether and to which extent farmers used organic fertilizers. The consideration of such variables would allow for a more sophisticated regression analysis. This would be a field for future research, once more integrated datasets are available.

For the most relevant crops we can contrast our results with reported ratios in literature. The ratio for paddy yields in AEZ3 (0.78) is below the range of paddy yield ratios reported in literature (0.86 to 1.05), while the ratio for AEZ2 (0.87) is just above the lower boundary (Ponti *et al.*, 2012). The potato ratios of 0.68 and 0.53 in AEZ2 and AEZ3 are either at the lower end or below the range of reported mean ratios for potato (0.65 to 0.7), which was determined only using data from developed countries ((Ponti *et al.*, 2012). Our results thus rather indicate a lower organic-to-conventional yield ratio in developing versus developed countries.

The substantial share of conventional production of paddy and potato in combination with high yield gaps explains more than half of the simulated decline in agricultural output (13.5%). However, it is not only the yield gap and share in production that matter, but also the consumer preferences as the example of maize shows. On a national level, we can contrast our results

only with the study by Jacobsen and Frandsen (1999), who find an higher decline in output. In one of their scenarios in which they simulate a 100% conversion under similar conditions, i.e. assuming no improvement in organic yields after conversion and allowing imports of animal feed, total output of the Danish agricultural sector declines by 20.4%. The cost of a large-scale conversion is arguably higher in a developed country such as Denmark, where the intensity of synthetic input use in CA is larger than in Bhutan. Hence, the lower estimate for the reduction in output in the context of Bhutan is consistent with the findings of Jacobsen and Frandsen.

Following the contraction in crop output, the 100% OA conversion leads to negative economic growth (1.1% decline in real GDP or about 20 million USD). This can be considered a substantial decline given that the crop sector comprises only about 7% of GDP in 2012. Tourist arrivals would need to more than double if the societal cost of converting to organic farming should be born from an increase in tourist royalties. From a distributional point of view, the cost of the 100% policy would largely be borne by non-agricultural households. Within rural households, particularly farmers in the temperate zone (AEZ3) would suffer from declining welfare. Arguably, the welfare effects are dependent to the degree to which households are willing to substitute domestic with imported produce as the price level of the latter is not impacted by the 100% OA policy. The chosen model setup aggregates imports and domestic goods according to a national substitution elasticity, without any consideration of household specific preferences. The substitution of local food by imports is reflected in the decreased degree of food self-sufficiency. In this context, the decline in paddy output is most sensitive highlighting the need to devote more resources to increase efficiency in organic paddy production, if the current degree of self-sufficiency is to be maintained.

From an agronomic perspective the model results are in line with ex-ante expectations regarding the impacts on land supply and nutrient availability. For rainfed-land and orchards, the model results imply expansion of land supply, while supply of irrigated-land declines. This is not only

due to declining competitiveness of paddy cultivation, but also due to aspects of land mobility. By Bhutanese laws, only paddy may be cultivated on land that is classified as wetland, i.e. irrigated-land. Model results would differ significantly if laws officially allowed for other crops to be cultivated on irrigated-land. However, this would have negative consequences for paddy cultivation, as irrigated-land would then increase in price. In reality, many farmers cultivate other crops than paddy on irrigated-land, therefore, we probably underestimate the effects of the 100% organic policy on rice self-sufficiency.

The strong decline in supply of N (-22.2%) reflects the lower amount of N in manure compared to typical synthetic fertilizers and explains a considerable share of the observed yield gap between OA and CA. N can be supplied from other organic fertilizers than manure. However, the potential of biological fixation of N through cultivation of legumes appears to be underutilized. Pulses, for instance, represent only about 3% of total cultivated area in Bhutan. The limited availability of water and labour seem to constrain farmers from growing more legumes, whether as crops or green manure in their crop rotations (Tashi, 2015). Legumes together with leaf litter and recycled materials from crop and household waste still play a minor role in Bhutanese agriculture. Their potential for farming systems in Bhutan need to be addressed by future research.

While the 100% conversion would lead to more labour required for crop production, agricultural wages nevertheless decline due to lower yield levels and lower demand for agricultural labour in other activities. This finding contradicts claims found in the literature that a large-scale OA conversion would benefit rural labour markets (Badgley *et al.*, 2007; Reganold and Wachter, 2016). Our model does not allow for a migration of labour between agricultural and non-agricultural sectors. Non-agricultural wages are reduced at higher rates than agricultural wages, which implies that allowing migration between agriculture and non-agriculture sectors would result in agricultural wages falling even more.

Reganold and Wachter (2016) provides an extensive discussion on the advantages of OA inter alia regarding environmental conservation, health and (if premium prices exist) farm income. The environmental benefits are the most relevant in the context of Bhutan's 100% OA conversion policy. Including environmental benefits in our model framework, however, would go beyond the scope of this study. There has been no research or data documenting the potential magnitude of environmental benefits from OA in Bhutan. The magnitude is likely to be small, as cropland and orchards were estimated to comprise only 3.8% of total estimated value of ecosystems, while forests make up 93.8% (Kubiszewski *et al.*, 2013). Furthermore, it needs to be taken into account that any potential benefits would partially be offset by an increase in negative externalities occurring within India from where more conventionally produced food would be imported. This would be a leakage of the initial intent to conserve the environment. Input levels of agrochemicals, and thus also the risk of negative environmental externalities, are much higher in India and additional transportation would be necessary.

6. Conclusions and policy implications

We studied the Bhutan's policy to convert 100% to OA to understand the economy-wide effects of such an unprecedented large-scale conversion policy. Despite the country's low reliance on agrochemical inputs, we find a strong contraction in agricultural output and substantial losses in welfare. This is largely driven by lower organic yields, but also by other factors such as production shares of CA, consumer preferences and trade linkages. Trade dampens the negative effects, but leads to a larger dependency on imported food, thereby resulting in a trade-off with the government's objective of increasing food self-sufficiency. While land supply increases only slightly, availability of N becomes a bottleneck when converting to 100% OA. This is not only a problem of decreasing intensity of fertilizer use, but also of the lower relative N content in animal manure. The decline in N availability should raise awareness to increase the adoption

of organic fertilizers with biological fixation of nitrogen whose potential are currently underutilized in Bhutan.

Against claims in literature, we find no support that OA benefits rural labour markets, despite higher labour intensity. Hence, a 100% OA policy hurts all types of households, with the exception of farmers in low altitudes (AEZ1) where the reliance on agrochemicals is by far the lowest. There are model limitations that do not allow including all potential benefits from a 100% organic policy. These include potential environmental benefits and positive spill over effects, e.g. a boost in tourist arrivals. Further research is needed to adequately address these aspects that go beyond the scope of this study. However, even in the favourable context of Bhutan, it is uncertain whether these positive effects would outweigh the magnitude of negative economic consequences of a 100% organic policy. We can conclude that even with a low reliance on agrochemicals a country within a similar context faces substantial economic cost under a 100% organic conversion policy.

As Bhutan continues to have strong growth rates in the industry and service sectors, agriculture is becoming less important lowering the economic costs of achieving 100% OA relative to the economy as a whole. Still, agriculture will remain the mainstay for a large group of Bhutan's population. While there are numerous efforts to make agriculture more productive and commercial, a large-scale conversion is likely to mimic a production tax on the cropping sector, however without the opportunity of redistributing any tax income.

Therefore, the 100% OA policy collides with current agricultural policy objectives, particularly the objective to increase food self-sufficiency. This conflict is difficult to avoid as excluding the paddy sector would entail risks of agrochemicals leaking into other cropping activities. Furthermore, the appeal of aiming at less than 100% OA will lower the potential of branding Bhutan as a genuine organic and green country. Any policy impacting trade has to comply with

Bhutan's free trade agreement with India. A non-discriminatory measure would be to tax all agricultural goods that were not produced under organic standards, hence an effective import tax on most agricultural goods. However, this would further increase agricultural prices. A similar option would be to introduce sales taxes on agricultural produce which could be rebated as production subsidies. This would lower relative prices of local produce, but simultaneously provoke the risk of consumer protests in urban areas. As 100% organic is likely to benefit the tourism sector, policymakers could alternatively increase the tourism royalty in order to compensate farmers for lower productivity. This would benefit both farmers and consumers, yet the tourist's willingness to accept such an increase in royalty is uncertain.

Although it might be politically desirable to achieve 100% organic within a certain time period, a fiscal policy (e.g. tax on agrochemicals) could instead lead to a more efficient, albeit only partial OA conversion. In Bhutan, levels of agrochemical use are low, which can imply high marginal-benefits while causing low marginal-damage to the environment. Hence, from an efficiency point of view, taxing agrochemical inputs would allow to reduce their usage where they are least efficient, while still allowing them where they provide a high benefit-cost ratio.

At the current stage, the potential of an optimised organic farming system in Bhutan remains unclear. The focus of Bhutan's government seems to be on the production of "chemical-free food" while other aspects of OA being a holistic system are neglected (Seufert *et al.*, 2017). In order to increase yield levels of today's "organic farming by default", government investments in research and extension are necessary. Technology development (e.g. optimised fertilization strategies based in N-fixation by legumes, development of plant-based pesticides, breeding of adapted crop varieties, improvement of mixed farming systems with animal husbandry) for an intensification of the traditional agricultural systems is needed to improve yields in OA. Besides more time consuming research efforts and short-term dissemination of best-practice examples (peer-to-peer extension), demonstration farms and intensive training of extension workers could

reduce the societal conversion costs. Another way to capitalize on the distinct advantages of OA might be tapping organic export markets, particularly for high-value niche products. Yet, this again could compromise food self-sufficiency. Generally, policymaking within Bhutan's agricultural sector should recognize the trade-offs of conflicting policy objectives (e.g. OA versus food self-sufficiency) and prioritize accordingly.

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