Farmers' motivations to adopt agronomic innovations and other livelihood improvement strategies

A case study of smallholder farming systems in the Central Rift Valley and Jimma, Ethiopia

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Abstract

To ensure that enough maize will be produced to feed Ethiopia's rapidly increasing population, the limited adoption of agronomic innovations by smallholder farmers need to be addressed. Despite the focus of agricultural research for development (R4D) on this issue, farmers' reasons for (not) wanting to adopt agronomic innovations have not been sufficiently understood. Previous research has also not assessed whether farmers' perceive the agronomic innovations to be superior to other livelihood improvement strategies already known to them. This research addressed this knowledge gap for two innovations, improved fertilization and an increased planting density, introduced by researchers into two regions in Ethiopia, the Central Rift Valley (CRV) and Jimma. Through open ended interviews, this study identifies farmers' goals, perceived livelihood improvement strategies and factors enabling or constraining implementation of those strategies. On the basis of these findings, a second round of close-ended interviews was performed to quantify the performance and advantage of the two innovations. The results revealed that farmers' most important goals were to increase the food security and living standard of their families. Both strategies applicable to farmers production of maize only, and strategies affecting the entire productivity of their farms (e.g. allocation of maize land to cash crops) were considered to be well aligned with these goals. One of researchers innovations, increasing the planting density of maize, was among those well aligned strategies, but the other, improved fertilizer management, was not. In Jimma farmers' perceptions of the relative advantage of the innovation may be attributed the many constraints inhibiting farmers from adopting it. In CRV, however, farmers' poor perception of the performance of increased planting density can probably be attributed to the fact that no response in maize yield to increased planting density was observed. In addition to researchers' innovations, many other livelihood improvement strategies were identified. Many of these strategies tended to be complementary, which implies that knowledge about farmers perceptions of them is needed to understand farmers adoption decisions. Combined implementation of both maize strategies and wider farm management strategies was put forward as the most promising means for farmers to achieve their goals. Most farmers, however, were not currently able to implement such management changes as they were constrained by their lack of financial capital, labour, knowledge, land and access to good quality inputs. These constraints would need to be addressed through policies or strengthened institutions for farmers to be able to improve their livelihoods.

1 Introduction

In both urban and rural Ethiopia, maize is the cheapest and most important source of calories (Abate et al., 2015). 95% of the cultivated maize area in Ethiopia is under the management of smallholder farmers, whom have benefitted greatly from increasing maize yields resulting in poverty reduction (Dercon et al., 2009; Zeng et al., 2018). Yet, the potential for increasing production of maize in Ethiopia is high, as maize production by smallholder farmers is still characterised by large yield gaps, ranging up to 10 tonnes ha^{-1} (www.yieldgap.org). Addressing these yield gaps is of major importance in the face of rapid population growth (United Nations, 2017). Failing to do so results in Ethiopia becoming food self-insufficient by 2050 (van Ittersum et al., 2016). To maintain Ethiopia's current status of food self-sufficiency status, the two main factors limiting farm productivity increases, climatic vulnerability and limited adoption of agricultural innovations, need to be addressed (Abate et al., 2011; Pamuk et al., 2014). By assessing the likelihood of farmers' adoption of two agronomic innovations, improved fertilization and increased planting density, introduced in two regions in Ethiopia, the Central Rift Valley and Jimma, in 2017, this study focusses on the latter. The two innovations, referred to as researchers' innovations, were of interest due to their potential to increase maize yields to up to 50% of farmers' water-limited yield (Kenea, n.d.).

Adoption of agricultural innovations with potential to increase maize productivity, such as improved seeds, inorganic fertilizer, manure, irrigation and improved pest management, has been widely researched (e.g. Alem and Broussard, 2018; Amare and Simane, 2017; Ketema and Bauer, 2011; Murage et al., 2015; Zeng et al., 2018, 2015; Appendix 7.1). Such studies identify strata of farmers which are less likely to adopt agricultural innovations (e.g. old, conservative farmers) and situations in which farmers do not apply agricultural innovations (e.g. when they do not expect yield responses as or when the investment costs are too high) (Fufa and Hassan, 2006). Such knowledge is essential to develop sound policy and research recommendations (e.g. crop loss insurance schemes and maize drought-tolerant varieties) (Fufa and Hassan, 2006). Such studies do not, however, provide insight into whether the agricultural innovations contribute to farmers' personal goals. To gain such insight, farmers' perceptions of the suggested agricultural innovations should be compared to farmers' perceptions of their baseline management and a wide range of complementary practices that could also, potentially, contribute to farmers' goals.

Adoption studies have typically focused on one, or a few, agricultural innovations in isolation (Ahmed et al., 2017; Appendix 7.1), while farmers decisions to adopt innovations is based on their perceived (dis)advantages compared to other available innovations. That is, farmers' decision to (not) adopt an innovation depends on farmers' perceptions of the *relative* advantage of that innovation (Gutman, 1997; Pannell et al., 2006). We expand Sumberg's (2006) metaphor: for automobile salesmen to be successful, their automobiles need not only to fit into the contexts of their potential users, they should also be competitive with existing and alternative tools used to achieve the potential users goals (Dorfman, 1996;

Gutman, 1997). Research into adoption of agricultural innovations, thus, require methods that consider both the relative advantage of agricultural innovations (Dorfman, 1996; Pannell et al., 2006) and the fit of agricultural innovations into farmers' contexts (Sumberg, 2006; Ojiem et al., 2006).

Addressing this requirement, this study aims to develop and test a methodology that quantifies the relative advantage of agricultural innovations and other livelihood improvement strategies, assuming livelihood improvement is the overarching goal of all farmers (Knutsson, 2006). What livelihood improvement would look like for each farmer, however, was not predetermined but explored through interviews. Other strategies that farmers' perceive could improve their livelihoods were also explored. Based on farmers' goals for livelihood improvement, the relative advantage of researchers' innovations and of these other strategies was quantified so that they could be compared. The fit of researchers' innovations, and the other strategies, in farmers' contexts were also considered.

On the basis of the assumption that only strategies with a high relative advantage and a good fit in farmers' contexts will be adopted, we evaluated whether the agronomic innovations were likely to be adopted and, by extension, whether they could be expected to contribute to ensuring food self-sufficiency in Ethiopia by 2050. To do so, we asked: 1) What are farmers' goals for livelihood improvement? 2) Which strategies do they perceive could contribute towards reaching those goals? 3) Which factors constrain or enable farmers' implementation of these strategies? 4) What criteria do farmers' use to evaluate whether researchers' innovations are superior to their baseline management? 5) Do farmers perceive researchers' innovations as superior to their baseline management? 6) Which strategies are most likely to be adopted given farmers' contexts and their perceptions of relative advantage?

2 Methodology

2.1 Research context

This research was performed in the context of the TAMASA (Taking Maize Agronomy to Scale in Africa) project that is managed by Wageningen UR and CIMMYT (Appendix 7.1): “Maize Yield Gaps and their Mitigation in Ethiopia: Exploration and Redesign”. The project had a series of on-farm experiments installed in Adami Tulu in the Central Rift Valley (CRV) and Kersa in Jimma (Fig. 1) in 2017 and 2018. The experiments were used to assess the impact of researchers’ innovations (Tables 1 & 2) on maize yield.

2.2 Study sites

The study sites in the CRV and Jimma had differing agro-ecologies. The CRV site was low-altitude (1200 – 1800 m.a.s.l), with a semi-arid to arid, warm climate (monthly average temperatures range from 14 - 27°C) and two rainy seasons, one from March to May and one from July to September (Getnet et al., 2016; Silva et al., 2016). The average annual precipitation in the CRV is 750 mm, but tends to be erratic and droughts are recurrent (Getnet et al., 2016). The Jimma site was mid-altitude (1600 – 2600 m.a.s.l), with a sub-humid to humid, warm climate (monthly average temperatures range from 13 - 28°C) and a rainy season from March to November and a dry season from November to February (Duguma et al., 2017; TAMASA, 2016). In Jimma, the average annual precipitation is 1520 mm and less erratic than in CRV (Kenea, n.d.).

Figure 1. Location of study areas CRV (1) and Jimma (2).

The study sites also differed in socio-economic characteristics. The average household in CRV had 20.6 (±0.5) household members, 10.4 (±7.0) assets, 4.0 (±3.7) hectare (ha) of cropland and 10.0 (±9.8) tropical livestock units (TLU) (Silva et al., 2016). The average household in Jimma had 6.6 (±1.7) household member, 16.3 (±12.0) assets, 1.6 (±0.6) ha of cropland and 7.9 (±5.2) TLU (TAMASA, 2016).

2.3 Researchers’ innovations

The practices trialled on-farm in 2017 and 2018, referred to as researchers’ innovations, were increased rates of inorganic fertilizer applied in split (Table 1, Improved) and increased planting density (Table 2, Narrow). The innovations were developed using a target-oriented approach and should, in theory, enable farmers to reach 50% of their water limited yield (Kenea, n.d.). For the purpose of this research, the two components of the improved fertilizer innovation, increased rates of inorganic fertilizer and an increased number of inorganic fertilizer applications were distinguished since farmers might want to adopt only one of the components (e.g. Ronner et al., 2018). Baseline experimental treatments with farmers' current most common practices were also trialled to enable farmers to evaluate the benefits of researchers' innovations. A control treatment without any inorganic fertilizer was also included (Table 1). The experimental treatments were combined in a factorial design on each farm. The varieties used in the experiments were the varieties most commonly planted by farmers, BH540 in CRV (Silva et al., 2016) and BH661 in Jimma (TAMASA, 2016). Planting (2 seeds per hole, later thinned to one) and inorganic fertilizer placement (next to seeds) was done by hand instead of by oxen as was common practice.

Table 1. Fertilization experiments in CRV and Jimma during the 2018 growing season. The 'Baseline' experimental treatment functioned as a reference for farmers since it used the fertilization rates and the number of applications most common in the regions. The timing of the second and third fertilizer splits are given in days after maize emergence (DAE). All rates are in kg ha^{-1}.

Region	Treatment	Nutrient	at planting	21 DAE	35 DAE
CRV	control	N	-	-	-
		P	-	-	-
		K	-	-	-
	Baseline	N	10.75	10.75	-
		P	-	-	-
		K	-	-	-
	Improved	N	13.6	13.6	13.6
		P	-	-	-
		K	-	-	12.2
Jimma	control	N	-	-	-
		P	-	-	-
		K	-	-	-
	Baseline	N	26.5	26.5	-
		P	30	-	-
		K	-	-	-
	Improved	N	50	50	50
		P	9	-	-
		K	-	-	131

Table 2. Planting density experiments in CRV and Jimma during the 2018 growing season. The 'Wide (baseline)' experiment functioned as a reference for the farmers since it used the most common plant population density, row distance and within-row distance used by farmers the regions.

Region	Treatment	Parameter	Value
CRV	Wide (baseline)	plant population (ha^{-1})	32443
		row distance (m)	0.75
		within-row distance (m)	0.40
	Narrow (increased)	plant population (ha^{-1})	53333
		row distance (m)	0.75
		within-row distance (m)	0.25
Jimma	Wide (baseline)	plant population (ha^{-1})	27724
		row distance (m)	0.80
		within-row distance (m)	0.45
	Narrow (increased)	plant population (ha^{-1})	62000
		row distance (m)	0.50
		within-row distance (m)	0.32

2.4 Farmer selection

A sample of farmers was selected from three larger groups of farmers with differing levels of resource-endowment (Table 3) since farmers differing in resource endowment were expected to be subject to different factors constraining or enabling adoption of the innovations (Table 3). The grouping was based on a qualitative assessment by the local agricultural extension services in CRV (Silva et al., 2016), and a cluster analysis in Jimma (Kenea, n.d.) (Table 3).

Table 3. Average resource endowment of selected farmers per resource endowment group (HRE = high resource endowment, MRE = medium resource endowment, LRE = low resource endowment) in CRV and Jimma.

	CRV			Jimma		
	HRE	MRE	LRE	HRE	MRE	LRE
Livestock (TLU)	12.0	6.7	3.5	10.9	8.2	4.1
Cropped area (ha)	4.5	3.2	2.5	2.0	1.4	1.4
Non-workers*	11.8	15.7	16.0	2.3	2.4	2.9
Farmers selected	4	3	3	5	2	3

*Household members that did not participate in agricultural activities, usually below the age of ten (Kenea, personal communication)

2.5 Theoretical framework and research approach

Since this research explored farmers' goals and livelihood improvement strategies, a critical realist approach was chosen (House, 2007). The critical realist approach focuses on identifying which mechanisms are most likely to cause (have caused) certain outcomes given the context in which the outcome will occur (has occurred) (Robson and McCartan, 2016). In line with the critical realist approach to finding explanations, we 1) made a list of mechanisms that could enable farmers to improve their livelihoods and 2) evaluated in which contexts these mechanisms might be expected to operate and in which they might not (Robson and McCartan, 2016) (Fig. 2). For our research, livelihood improvement ***strategies*** were interpreted as ***mechanisms***, ***contexts*** were described with ***factors*** enabling or constraining farmers' implementation of those strategies and the desired ***outcome*** was considered to be an ***improved livelihood***.

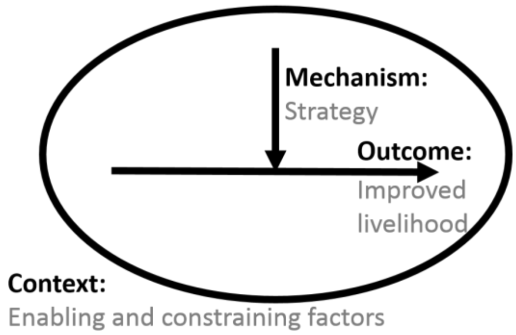


Figure 2. In black: Representation of the realist explanation after Robson and McCartan (2016). **In grey:** Our interpretation of the critical realist concepts.

To assess the relative advantage of researchers' innovations compared to farmers' baseline management and to other livelihood improvement strategies, data were collected in two steps. The first step identified: criteria used by farmers to assess the performance of researchers' innovations, strategies farmers perceived could improve their livelihood, goals perceived to drive farmers decisions, and factors affecting farmers' implementation of strategies. The second step compared researchers' innovations with farmers baseline management based on the criteria mentioned in step 1, and compared researchers' innovations to other strategies mentioned in step 1, based on goals and constraints mentioned in step 1. The two-step approach was adapted for personal interviews from Bellon's (2001) four-step approach for focus group discussions (Appendix 7.2) to avoid a bias towards more talkative farmers. The interview methods used in each step are described in more detail in 2.6 and 2.7.

2.6 Step 1 – Identifying farmers' criteria, strategies, goals and contexts

Interviews in this step were divided into three parts (Fig. 3). In the first part the a good interviewer-translator-interviewee relationship was established while basic data on farmers' personal, household and farm characteristics and management were collected. Farmers were asked to talk about themselves, about their family and farm and their management. If themes of interest (Fig. 3) were not covered, farmers would be prompted to talk about them, i.e. farmers would be asked directly what, for instance, their age was or how they managed their weeds.

The second part focussed on strategies farmers perceived to have the potential to improve their livelihood. Farmers were asked if there was anything about their current management that they would like to change and if there were any new management practices or technologies that they would like to implement in order to improve their livelihoods. The strategies, mentioned by each farmer, were noted down. For each strategy, farmers were prompted to tell us about their goals: Why did they want to implement it? What did they hope to achieve by implementing it? What benefits did they think this strategy could have for their farm or family? (Fig. 3). Further, farmers were also prompted to tell us about the factors influencing their implementation of the strategies: Were there any difficulties related to implementing the strategy? Were there any disadvantages of implementing the strategy? When would they like to implement the strategy? On how much land did they want to implement the strategy? (Fig. 3). No prompts as to which kind of strategies would improve farmers livelihood were given. Farmers were also not prompted to talk about factors that enabled them to implement livelihood improvement strategies (that other farmers might not be able to implement), since this was ill received by the first three farmers' interviewed[1].

The third part focussed on farmers' opinions of researchers' innovations (Tables 1 & 2, Fig. 3). Farmers were asked directly about their preferences regarding the number of inorganic fertilizer applications, the rate of inorganic fertilizer application and planting density in maize. They were also asked whether they wanted to adapt their management based on what they had observed in the experiments and, if applicable, why they wanted to adapt their management or what benefits they thought the adaptation would have for their farm or family. Furthermore, as in part 2, they were also asked whether there were any difficulties or disadvantages related to the adaptation of their management, when they actually wanted to adapt their management, and on how much land they would start implementing it (Fig. 3). As in part 2, farmers were not prompted to talk about factors that might enable[1] them to adapt their management.

[1] In order to prompt farmers to talk about factors that enabled them to implement livelihood improvement strategies, we had asked them whether there were any reasons why it would be easier (or harder) for them to implement a certain strategy than it would be for other farmers. The response we got to this question was that it was not good to talk about other people behind their backs.

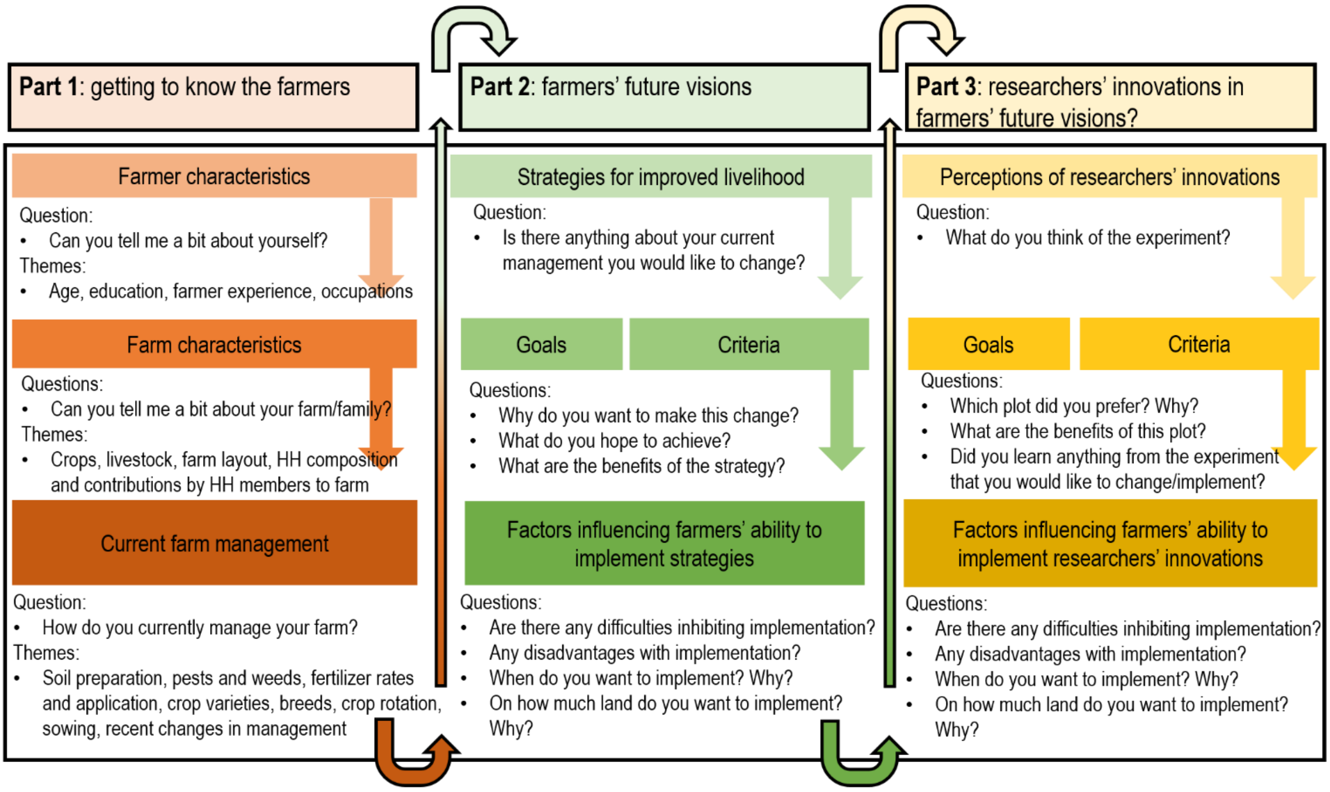


Figure 3. An outline of the themes and questions asked in the three-part semi-structured interviews in step

2.6.1 Data management

The interviews were often subject to disturbance (Appendix 7.3). In 4 out of the 20 recordings the audio quality was too poor to enable word-for-word transcription. The interviews of these four farmers were written out based on memory and notes taken during the interviews. The interviews of the other 16 farmers were transcribed word-for-word. The transcriptions and written-out notes were loaded to RStudio 1.1 (R version 3.5.0) (R core team, 2018) via the graphical user interphase (GUI) of the RQDA-package (Huang, 2018). The GUI of RQDA was also used to code the interviews to enable us to assess how often strategies, goals, criteria and factors influencing farmers' ability to implement strategies were mentioned by farmers (Chandra and Shang, 2017).

2.6.2 Interview coding

Inductive coding, also known as open coding (Gioia et al., 2012), was used to explore farmers' goals (Table 4), livelihood improvement strategies (Table 5), factors influencing farmers ability to implement strategies and/or reach their goals (Table 6), and criteria for evaluation of researchers' innovations (Table 7). Clear conditions (Tables 4 – 7) as to when a code was applicable were set in order to enhance transparency and qualitative rigour (Chandra and Shang, 2017; Gioia et al., 2012). To clarify at which farm system levels farmers wanted to implement strategies, strategy codes were categorized into maize strategies, crop strategies, cropland strategies, livestock strategies, farm strategies and household strategies (Table 5). Factor codes were categorized in accordance with self-determination theory concepts: autonomy, and knowledge and skill (Deci and Ryan, 2008) and livelihood concepts: financial capital, human capital, physical capital, social capital, technological capital and institutional factors (Knutsson, 2006) (Table 6).

In addition to goal codes, criteria codes, strategy codes and factor codes, we used attachment codes, i.e. codes carrying additional information about the goals, criteria, strategies or factors. "CurrentMech" or "FutureMech" were attached to each strategy code to specify whether the strategy had been mentioned as part of a farmers' current management or as a strategy they would like to implement. "Prompt" or "NoPrompt" were also attached to each mechanism code to specify whether a strategy had been mentioned as a response to a direct question about that strategy (which was typically the case in parts 1 and 3 of the interviews) or as a response to an open question (which was typically the case in part 2 of the interviews). "Enabling" or "Constraining" were attached to each factor code to specify whether the factor mentioned enabled farmers to reach their goals for livelihood improvement or constrained them from doing so.

Table 4. Goal codes (shaded, bold) and the condition for attachment of a goal code to a farmers' statement (shaded, italics). The meaning of each code is given to the right of the codes. Underlined goals were selected for further analysis in the step 2 interviews.

Goals: *These codes were used when farmers expressed that their motivation for maintaining present management or wanting to implement a mechanism was...*	
<u>FeedFamily</u>	...have more food and/or better food to feed their families with
FarmPhysCap	...improve the quantity or quality of physical capital used to support farm activities
ImproveCom	...provide a better life for the people within their community
LabourUE	...be able to use labour more efficiently
<u>LandUE</u>	...be able to increase productivity in order to reduce farm size or use more area for production of other commodities
<u>MoreIncome</u>	...maximize their income, irrespective of the risk of income failure
<u>MoreProd</u>	...maximize their production, irrespective of the risk of production failure
<u>ReduceCost</u>	...minimize the expenses that are invested in the production of farm outputs
<u>StableIncome</u>	...ensure that income, from year to year, was relatively stable, i.e. to reduce the risk of income failure
<u>StableProd</u>	...ensure that production, from year to year, was relatively stable, i.e. to reduce the risk of production failure
<u>StandardLiving</u>	...provide a better life for their families beyond food, i.e. good clothing, education and good housing
WorkEase	...increase the ease with which farm activities are done

Table 5 (next page). Strategy codes (shaded, bold) per strategy category (shaded, bold, italics). The condition for application of a strategy code was that farmers expressed that they thought implementing the strategy would improve their livelihood. Explanations of the meaning of each code is given to the right of the codes. Underlined strategies were selected for further analysis in the step 2 interviews.

Maize strategies: *Codes used for strategies farmers perceived would change the performance of their maize sub-system only*			
FertCloserSeed	...placing inorganic fertilizer closer to the planted seeds...	**Pesticides**	...pesticides, applied in maize at higher rates...
GreenMaize	...using more of their land to grow maize that will be harvested earlier in the growing season and sold in the cities as street-food...	**StableUrea**	...slow-release urea, an inorganic nitrogen fertilizer that releases nitrogen slowly, throughout the entire growing season...
MediumMaize	... a medium maize planting density, NarrowMaize < MediumMaize < WideMaize	**ThreeAppl**	...inorganic fertilizer, applied three times instead of twice or all at once...
MoreVarieties	...growing several different improved maize varieties instead of just one...	**TwoAppl**	...inorganic fertilizer, applied twice instead of all at once...
NarrowMaize	...a high maize planting density: 53333 plants ha^{-1} in CRV and 62000 plants ha^{-1} in Jimma...	**WideMaize**	... a low maize planting density: 32443 plants ha^{-1} in CRV and 27724 plants ha^{-1} in Jimma...
NewSowTechn	...sowing a maize in a different way than present...	**WideRows**	... a larger row distance than present...
PesticideDYI	...pesticides, made from local ingredients, used to protect stored maize...		
Crop strategies: Codes used for strategies farmers perceived would change the performance of their maize and/or other crop sub-systems			
BetterLandPrep	...improved preparation of land prior to the sowing of a crop...	**MoreFertilizer**	...inorganic fertilizer, applied at a higher rate than present...
Herbicides	...herbicides, applied in crops where no herbicides were currently applied or at a higher rate in crops where herbicides were currently applied...	**MoreWeed**	... more weeding than present...
Inoculum	...inoculum (nitrogen-fixing bacteria), applied in beans...	**NewVar**	...crops of a new, improved variety...
Cropland strategies: Codes used for strategies farmers perceived would change the performance of their whole cropping system			
Fallow	...leaving more of their cropland fallow...	**MoreVeg**	...using more of their land to grow vegetables...
Intercropping	...growing two or more crops together on one field during the same season...	**MoreWood**	...using more of their cropland to grow trees for wood...
Liming	...lime, applied on fields perceived to have poor soil quality...	**OtherGrains**	...using more of their cropland to grow grains other than maize...
Manure	...manure, applied on fields where no manure was currently applied or at a higher rate on fields were manure was currently applied...	**Rotation**	...not growing the same crop on the same field every year...
MoreCoffee	...using more of their cropland to grow coffee...	**SoilConservPrac**	...soil conservation practices, such as terracing or planting grass between fields on a slope...
MoreFruit	...using more of their cropland to grow fruit...	**Vermicompost**	...vermicompost, applied on fields where no vermicompost was currently applied...
Livestock strategies: *Codes used for strategies farmers perceived would change the performance of their livestock sub-systems*			
BuildFence	...a fence around the area where livestock are kept...	**NewBreed**	... livestock of a new, improved breed...
Farmland strategies: *Codes used for strategies farmers perceived would change the performance of their whole farm*			
MachineTools	...an investment in machinery or tools for farm activities...	**RentLand**	...renting land in order to grow more crops...
MoreCattle	...using more of their land and/or resources to keep cattle...	**MoreOthLivestk**	...using more of their land and/or resources to keep other livestock (not cattle)...
RentOutLand	...renting out part of their owned land to other farmers...	**WaterManage**	...collecting and redistributing rainwater or water from a river throughout the growing season...
Household strategies: *Codes used for strategies farmers perceived would change the performance of their household*			
Emigration	...moving to a city or another country...	**OffFarmWork**	...spending some of the time otherwise used for farm activities to do work in another sector...
EucalypManage	...a stricter set of regulations for planting eucalyptus...	**Trading**	...selling and buying commodities for a profit...
MeansTransp	...an investment in a cart, wheelbarrow and/or a donkey as a means of transport...	**WorkExchange**	...working for other farmers in exchange for having other farmers work at their farm...

Table 6. Factor-codes (shaded, bold), factor categories levels (shaded, bold, italics) and the conditions for application of factor codes, given per aggregation level are given (shaded, italic). Explanation of the meaning of each code are given for to the right of the codes. Underlined factors were selected for further analysis in the step 2 interviews.

***Autonomy** factor codes were used when farmers reported being (un)willing to implement a strategy because of their...*			
Age	...age	**Motivation**	...motivation (added when farmers expressed a lot of excitement and commitment to change)
ChatConsum	...consumption of chat	**<u>PercRelAdv</u>**	...perception of the relative advantage of one mechanisms above another
Ethics	...ethical beliefs	**PercRisk**	...perception of the risk of losing income or production
***Knowledge/skill** factor codes were used when the (lack of) knowledge/skill affected farmers ability to implement a strategy*			
Cashskill	...ability to invest their money in a good way	**<u>SkillMech</u>**	...skills useful for implementation of the mechanism
<u>KnowMech</u>	...knowledge of the mechanism		
***Financial capital** factor codes were used when the (lack of) financial capital affected farmers ability implement a strategy*			
<u>Cash</u>	...cash at the time when an investment is needed...	**Savings**	...savings of cash
OffFarm	...cash, sourced through off-farm activities		
***Human capital** factor codes were used when the (lack of) human capital affected farmers ability to implement a strategy*			
FamilyMembers	...family members	**SickFamMem**	...family members that could not contribute to the household due to sickness
<u>Labour</u>	...a labour force	**SkillWorkers**	...poorly skilled or lazy workers
***Physical capital** factor codes were used when the (lack of) physical capital affected farmers ability to implement a strategy*			
CoffeeStore	...coffee that can be sold when an investment is needed...	**<u>Land</u>**	...land
CropStorage	...crops that can be sold when an investment is needed...	**Livestock**	...livestock: cattle, sheep, goats, chickens, donkeys or bees
Disease	...a soil infested with diseases...	**Oxen**	...oxen, used for traction
Donkey	...a donkey to be used as a means of transport...	**SoilFert**	...fields with a good/poor soil fertility
FoodSupply	...a sufficient supply of food for household...	**Trees**	...trees that can be used to harvest fruit or wood...
***Social capital** factor codes were used when the (lack of) social capital affected farmers ability to implement a strategy*			
Cooperative	...a cooperative membership...	**LinkResearch**	...a link to a research project, researcher or company doing research or research facility...
FarmerNetwork	...a network of farmers with whom they could get support and exchange information...	**Relatives**	...relatives...
***Technical capital** factor codes were used when the (lack of) technical capital affected farmers ability to implement a strategy*			
Cement	...cement...	**LivestockHouse**	...a facility to house livestock...
Ditch	...a ditch to be used for the collection of water or manure...	**ToolsEquipment**	...tools and/or equipment
Fence	...a fence keeping the livestock protected from predators and the crops protected from livestock...		
***Institutional factor** codes were used when regional institutional factors affected farmers ability to implement a strategy*			
AccessWater	...legal access to local water sources...	**<u>InputAvail</u>**	...timely access to sufficient inputs for agricultural activities...
Corruption	...corruption by agricultural extension services...	**<u>InputQuality</u>**	...access to inputs of sufficient quality for agricultural activities...
Credit	...access to institution providing credit...	**MeTransAvail**	...access to means of transportation (carts or wheelbarrows)...
DemandMarkt	...market demand for a certain commodity...	**NoRegulations**	...lack of regulatory measures...
ExtensAdvice	...advice from agricultural extension services...		

Table 7. Criteria codes (shaded, bold) and the condition of attachment of a code to a farmers' statement (shaded, italics). The meaning of each code is given to the right of the codes.

Criteria: These codes were used when farmers expressed that their reason for preferring researchers' innovations to their baseline management or vice versa was that their preferred option	
AirCirc	...had good air circulation within the maize stand
CobNumber	...provided a good number of maize cobs
CobSize	...provided good sized maize cobs
Colour	...had nicely coloured maize plants
GrainWeight	...provided a good weight of maize grains
Profit	...provided a good profit
Resistance	...had a maize strong stand that could resist pests, diseases, drought or heavy rainfall
Yield	...provided a good maize yield

The interviews were coded in three consecutive coding rounds. In the first round, goal, criteria, factor and strategy codes (Tables 4-7) were only added to part 2 and 3 of the interviews (see Appendix 7.4 for more detail). In the second coding round, farmers' current management practices were considered in the light of the previous coding round: if a current management practice of one farmer had been mentioned as a strategy by another farmer, it would be coded as a strategy (with the attachment-code "CurrentMech"). Factors and goals mentioned in relation to such management practices were also coded. In the third round, we used co-occurrence matrices that showed which combinations of goals, strategies and factors each farmer talked about during their interviews (see Appendix 7.5 for figures and supplement 2 for R-script). The co-occurrence matrices were made to check and improve the consistency of the coding and to enhance transparency (Gioia et al., 2012).

2.6.3 Interview analysis

To explore which strategies farmers perceived could contribute to their goals for livelihood improvement, specific combinations of goal codes and strategy codes were assessed and counted per farmer and region. To explore the factors influencing farmers' implementation of strategies, combinations of strategy codes and factor codes were assessed and counted per farmer and region. To assess whether strategies were mentioned with or without prompts from the interviewer and were already part of their current management or not, the number of times each combination of goal and strategy codes occurred in combination with the "FutureMech"/ "CurrentMech" and "Prompt"/ "NoPrompt" attachment codes was also counted. To assess whether factors were constraining or enabling, the number of times each combinations of factor and strategy codes occurred in combination with the "Enabling"/ "Constraining" attachment codes was counted.

Code combinations were counted and visualised in accordance to the number of farmer interviews in which they occurred. When code combinations occurred several times within one interview, only the first occurrence was counted. This was done to prevent a bias towards more talkative farmers. All coded statements were saved in an .rqda-database, which was accessed using DB browser for SQLite (Bi, 2009). To visualise the results, the database was loaded to RStudio using the RQDAQuery function (Huang, 2018), and plotted using ggplot2 (Wickham, 2016). 13 strategies were selected for further investigation in the step 2 interviews. The selection consisted of researchers' innovations (three applications of inorganic fertilizer, higher rates of application of inorganic fertilizer, a narrow planting density and a wide planting density), two strategies from which farmers currently seemed to benefit greatly and the 7 strategies mentioned non-prompted by most farmers as future strategies. The 8 most common out of all 12 identified goals motivating farmers to implement these strategies were also selected and so were the 6 most common factors constraining their implementation.

2.7 Step 2 – quantifying the relative advantage of researchers' innovations

In this step, interviews contained four parts (Fig. 4). In the first part, the average yield increases in response to researchers' innovation, as well as the individual yields of each farmer, were shown to farmers (Fig. 5; Kenea, n.d). In the second part, farmers were asked to rank the importance (8 = most important, 1 = least important) of various performance criteria (Table 7) specific to researchers' innovations. They were also asked to score whether they thought the innovations performed well in accordance with those criteria (2 = agree, 1 = partially agree, 0 = do not agree). In the third part, farmers were asked to indicate for each of the selected strategies (Table 5) whether they thought this was something they "didn't want to try", "already did enough", "would like to try, but thought might be difficult to implement" or "would implement without difficulty". For the strategies they "would like to try, but thought might be difficult to implement", they were asked to indicate which factors (Table 4) were constraining implementation. In the last part, farmers were asked to rank the importance (8 = most important, 1 = least important) of the selected goals (Table 4). They were also asked to score whether they thought the implementation of the strategies would enable them to realise those goals (2 = agree, 1 = partially agree, 0 = do not agree).

2.7.1 Quantification of the performance of researchers' innovations

The rationale behind collecting the data in part 2 (Fig. 4) was to enable comparison of farmers' performance perceptions of researchers' innovations and their baseline management. The average perceived relative performance (*RP*) of farmers baseline management and researchers' innovations was calculated for all farmers ($f \in 1\text{-}Nf$), per region according to the importance (I) of each criteria j and the score given to each of the baseline or innovation i:

$$\boldsymbol{RPi} = \frac{\sum_{f=1}^{Nf}\sum_{j=1}^{Nj}\frac{Ijf \,*SCOREijf}{Imax*SCOREmax}}{Nf*\frac{\sum_{I=1}^{Imax} I}{Nj}} * \mathbf{100\%} \qquad (1)$$

Ij refers to the importance of criteria j ($j \in 1\text{-}Nj$), and $SCOREijf$ refers to a farmers f's score given based

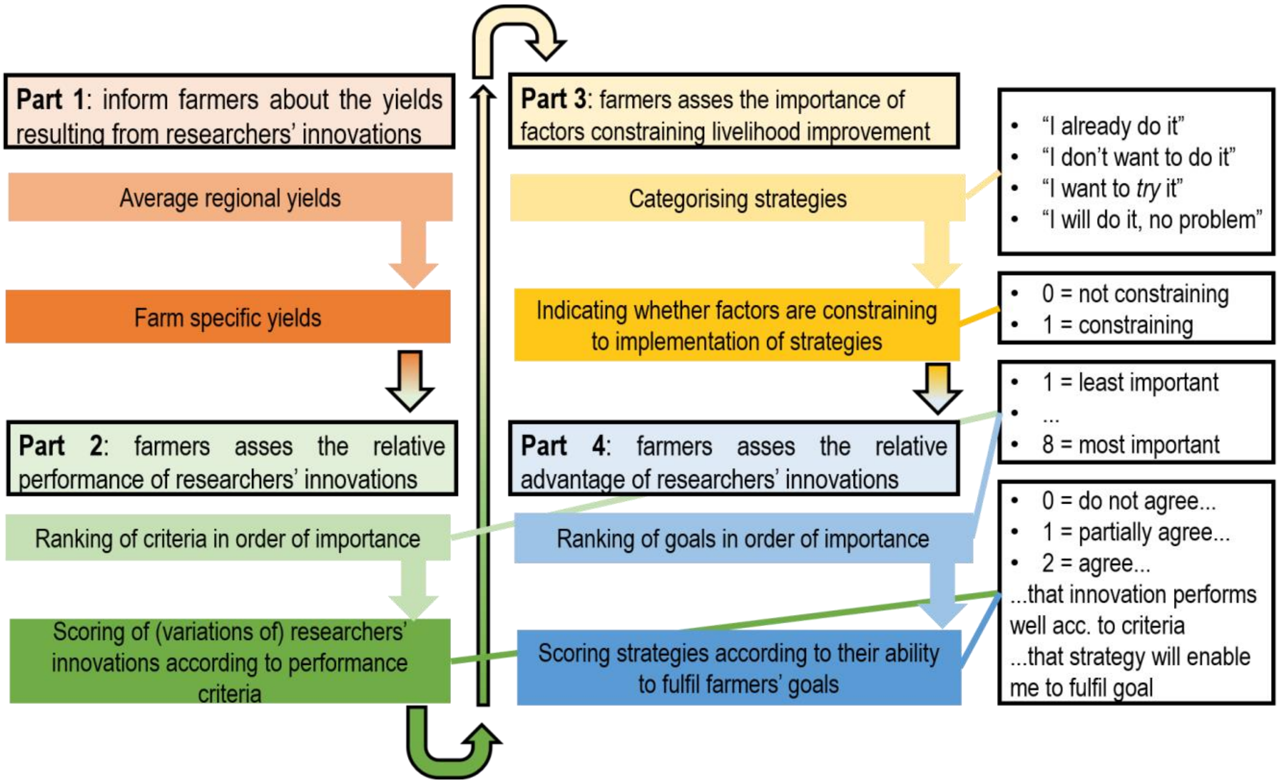


Figure 4. An outline of the activities and types of data collected in the different parts of the step 2 interviews

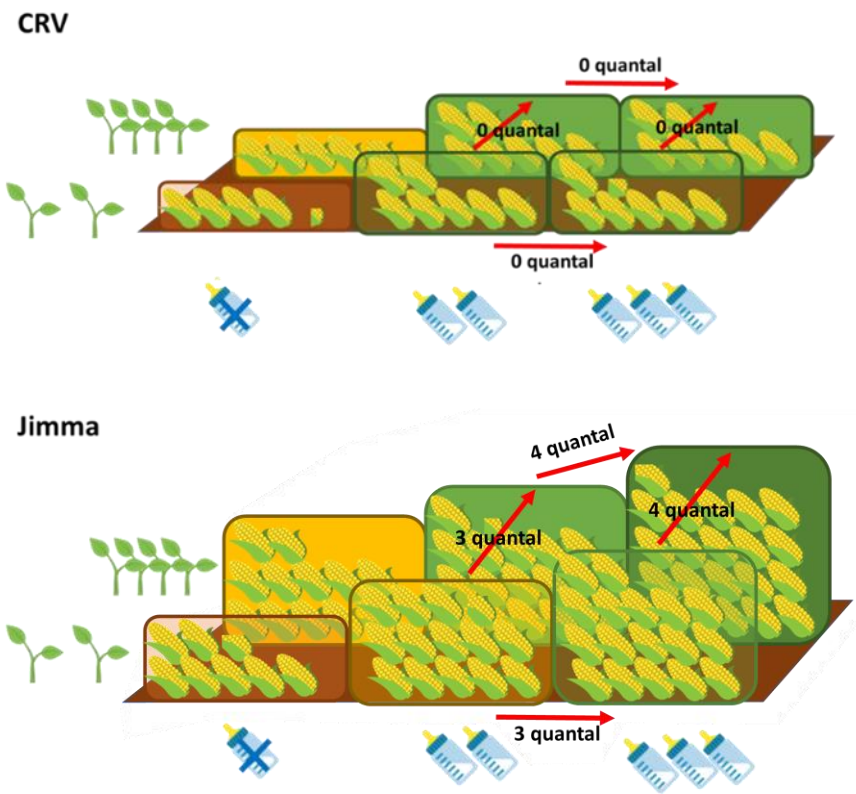


Figure 5. The average response (red arrows) to researchers' technologies in CRV and Jimma in the 2018 growing season. The magnitude of the response was given in the local unit, quantal per facasa (100 kg per ¼ hectare) in order to enable farmers to relate the results to their current management. One maize cob represents one quantal. Treatments along the y-axis are: High density (improved) and low density (baseline). Treatments along the x-axis are: Control (no fertilizer), baseline fertilizer and improved fertilizer.

on their perception of the performance of baseline or innovation *i* according to criteria *j*. *Imax* refers to the highest possible importance rank (8), and *SCOREmax*, refers to the highest possible score (2). *RPi* ∈ 0%-100%, where 0% would mean that every single farmer disagreed that baseline or innovation *i* performed well according to any of the *Nj* criteria and 100% would mean that every single farmer agreed that baseline or innovation *i* performed well according to all *Nj* criteria.

To evaluate whether farmers' performance ratings were aligned with the actual yields obtained in the on-farm trials, a visual correlation analysis of farmers' individual perceived relative performance versus farmers actual yields was performed. Since researchers' innovations were tested in a factorial design, average yields of each treatment factor (planting density, number of applications and inorganic fertilizer rate) were used.

2.7.2 Quantification of the relative advantage of researchers' innovations and constraints to adoption

The rationale behind collecting the data in part 3 and 4 (Fig. 4) was to enable adoption likelihood to be assessed on the basis of farmers' perceptions of the relative advantages of livelihood improvement strategies, including researchers' innovations, and the constraints inhibiting them from doing so. The relative advantage (*RA*) of each strategy *i* was calculated using equation 1. Goals *j* for livelihood improvement (Table 4) were used instead of criteria (Table 7). *SCOREijf* was the score given by a farmer *f* based on their perception of the contribution of strategy *i* to goal *j*. *RAi* ∈ 0%-100%, where 0% would mean that every single farmer disagreed that strategy *i* enabled farmers to reach any of the *Nj* goals and 100% would mean that every single farmer agreed that strategy *i* enabled farmers to reach all *Nj* goals.

To assess the influence of constraints on the regional implementation of strategies, the percentage of farmers (*f* ∈ 1-*Nf*) who had not already implemented a strategy *i* (*ADOPT GAPi*) and who reported that a constraint *c* was inhibiting their implementation of a strategy *i* (*ADOPT GAPic*) were calculated per region:

$$\boldsymbol{ADOPT\ GAPi} = \frac{\sum_{f=1}^{Nf}\sum_{i=1}^{Ni}\boldsymbol{TRYif}}{\boldsymbol{Nf}} * \mathbf{100\%} \qquad (2)$$

$$\boldsymbol{ADOPT\ GAPic} = \frac{\sum_{f=1}^{Nf}\sum_{i=1}^{Ni}\sum_{c=1}^{Nc}\boldsymbol{TRYif} * \boldsymbol{CONSTRicf}}{\boldsymbol{Nf}} * \mathbf{100\%} \qquad (3)$$

TRYif is a binary variable that refers to whether farmer *f* reported already "doing enough of" strategy *i* (given a value 0) or "did not want to implement strategy *i*", "wanted to try to implement strategy *i*, but thought doing so might be difficult” or “would implement strategy *i* without difficulty” (given a value 1*)*. *CONSTRicf* is also a binary variable that refers to whether a constraint *c* ($c \in 1\text{-}Nc$) is inhibiting a farmers *f* from implementing a strategy *i*.

2.7.3 Statistical analysis

Multiple paired Wilcoxon rank sum tests (Mann and Whitney, 1947) were used to evaluate whether there were significant differences ($p < 0.05$) between the distributions of: the importance ranks of the different criteria or goals, the relative performance (*RP*) scores of researchers’ innovations and farmers’ baseline management and the relative advantage (*RA*) of the selected livelihood improvement strategies. To prevent inflation of type I errors, Hochberg and Benjamini's (1995) procedure for p-value adjustment was used.

2.8 Interview setting

The step 1 interviews were conducted in CRV in the period 15.10 – 22.10 and in Jimma in the period 25.10 – 2.11 in 2018. With the exception of three farms in Jimma, the harvest was carried out together with the farmers and their families. In most cases, interviews were performed in the farmers yard after the harvest. In cases where the interviews this was not possible, an appointment was at the farm another day. Once, however, a farmer was interviewed at another farm and twice farmers were interviewed in our car in a nearby town. A researcher from the TAMASA-project functioned as a translator. The interviews were recorded and notes were made during the interviews to support transcription and analysis of the recordings. The step 2 interviews were conducted by an Oromic-speaking researcher from the TAMASA project in regional farmer training centres between 20.2 - 24.2 in CRV and 25.2 - 28.2 in Jimma in 2019. Part 1 of the interviews was a group discussion with all farmers from the same region. Parts 2 - 4 were conducted individually with each farmer. Financial compensation was given to farmers upon completion of both the interviews as a token of appreciation.

3 Results

3.1 Livelihood improvement strategies and farmers' motivations for wanting to implement them

This section describes the livelihood improvement strategies farmers reported wanting to implement to improve the performance of their maize sub-systems only (3.1.1), their maize or other crop sub-systems (3.1.2), their whole cropland (3.1.3), their livestock sub-system (3.1.4), their whole farmland (3.1.5) and their households (3.1.6). To enable easy navigation, each strategy, when introduced, is bold and underlined.

3.1.1 Maize strategies

Application of inorganic fertilizer twice during the growing season, was a practice that was part of the baseline management of more than half of the farmers in both CRV and Jimma (Fig. 6). Farmers who currently only applied inorganic fertilizer once all said they wanted to start applying inorganic fertilizer in split. None of the farmers had **applied inorganic fertilizer thrice** prior to the introduction of researchers' innovations in 2017. One farmer, however, had trialled the practice in the 2018 growing season. This farmer was the only farmer who mentioned wanting to adopt the practice without being prompted by the interviewer. When asked directly, however, 6 farmers in CRV and 7 farmers in Jimma said they would like to apply inorganic fertilizer three times. Farmers' motivation for adopting split fertilizer application was to increase their production of maize (Quote 1). The farmers that did not want to increase their number of applications to three, thought the third application would not have a (large) positive effect (Quote 2).

"Now we are not applying urea in the seedling stage. If that application of urea is increased for maize, it will increase the production and that will improve my situation. Now we are mixing urea and DAP during planting. After that [planting] we do not do anything. We are in discussion to implement this technology. In a group of farmers."

Quote 1, HH23 (CRV)

"When you apply fertilizer when it is dry, it burns my crop. [...] It is difficult to deal with the lack of rain. If you do the application three times, that is anyway not good. There is not enough rain in this surrounding. The third application is not important. It does not go with our environmental conditions."

Quote 2, HH39 (CRV)

Increasing or **decreasing the planting density of maize** were, similar to split fertilizer application, strategies that none or only one farmer talked about wanting to implement in the future without being prompted by the interviewer (Fig. 6; Appendix 7.8). When asked directly, however, most farmers in CRV said they wanted to adopt a wide planting density and most farmers in Jimma said they wanted to adopt a narrow planting density. Two farmers in Jimma and one in CRV said they wanted to adopt a **medium planting density**. The goal of decreasing the planting density was chiefly to increase whole-farm production. Adoption of a narrow or medium planting density, however, were also motivated by the desire for increasing land use efficiency. Farmers who judged wide maize to perform better than narrow maize tended to value large cob sizes and good air circulation within their maize stands (Quote 3), whilst farmers who judged narrow maize to perform better assessed the overall yield to be superior despite smaller cob sizes because of an increased number of cobs.

HH31: ***"This year due to the [irregular] rainfall, I haven't seen much difference, but last year it was clearly indicated that the low density was more productive than the high density. There is air circulation in the low density, and big cobs in the low density"***

Interviewer: "*You currently have quite a high density in your fields. Do you think you will change that based on what you observed?"*

HH31: "***I am going to re-check the high density and the low density. I am going to check by myself to see what is the difference"***

Quote 3, HH31 (CRV)

Most maize strategies were mentioned by a few farmers only. **Growing several different varieties** was a way for farmers to deal with the limited availability of improved seeds, but also a way to reduce the risk of harvest failure. **Sowing the maize in a different way, placing inorganic fertilizer closer to the planted maize seeds** and **widening the row distance** were strategies farmers learnt from the on-farm experimental trials even though this was not the intention of the researchers (Kenea, personal communication). The two farmers that said they wanted to implement the new sowing technique (by hand, at regular intervals and with 2 seeds per hole thinned after emergence) and the new fertilizer placement technique wanted to do so to increase their production. An increased work ease and labour use efficiency was important to the two farmers wanting to widen the rows between their maize plants. **Application of slow-release urea, pesticides** against maize weevil and **protection of stored maize with (home-made) pesticides** were strategies mentioned by one farmer only. The farmer wanting to apply slow-release urea thought this strategy was superior to split application because it was easier to apply and would give a higher yield due to less damage to the maize plants (Quote 4). The farmer that wanted to apply more pesticides wanted to increase his production to ensure his family would be food secure. In case pesticides were not available on the market he would use home-made pesticides.

"That stable urea is very important. There is no need of splitting if you have stable urea. If there is no splitting, oxen do not get into the field and there is no damage on the seedling in that stand. Otherwise, oxen crash some seedlings. It is better to apply fertilizer at once in the beginning. Then you don't go into the field. You will [only] go at the end during harvesting. And you do not lose plants because of crushing. So the stable urea and the pre-emergence herbicide is very important. I use pre-emergence herbicides in maize and haricot bean, but for the future I want to use [it] in all crops."

Quote 4, HH4801 (Jimma)

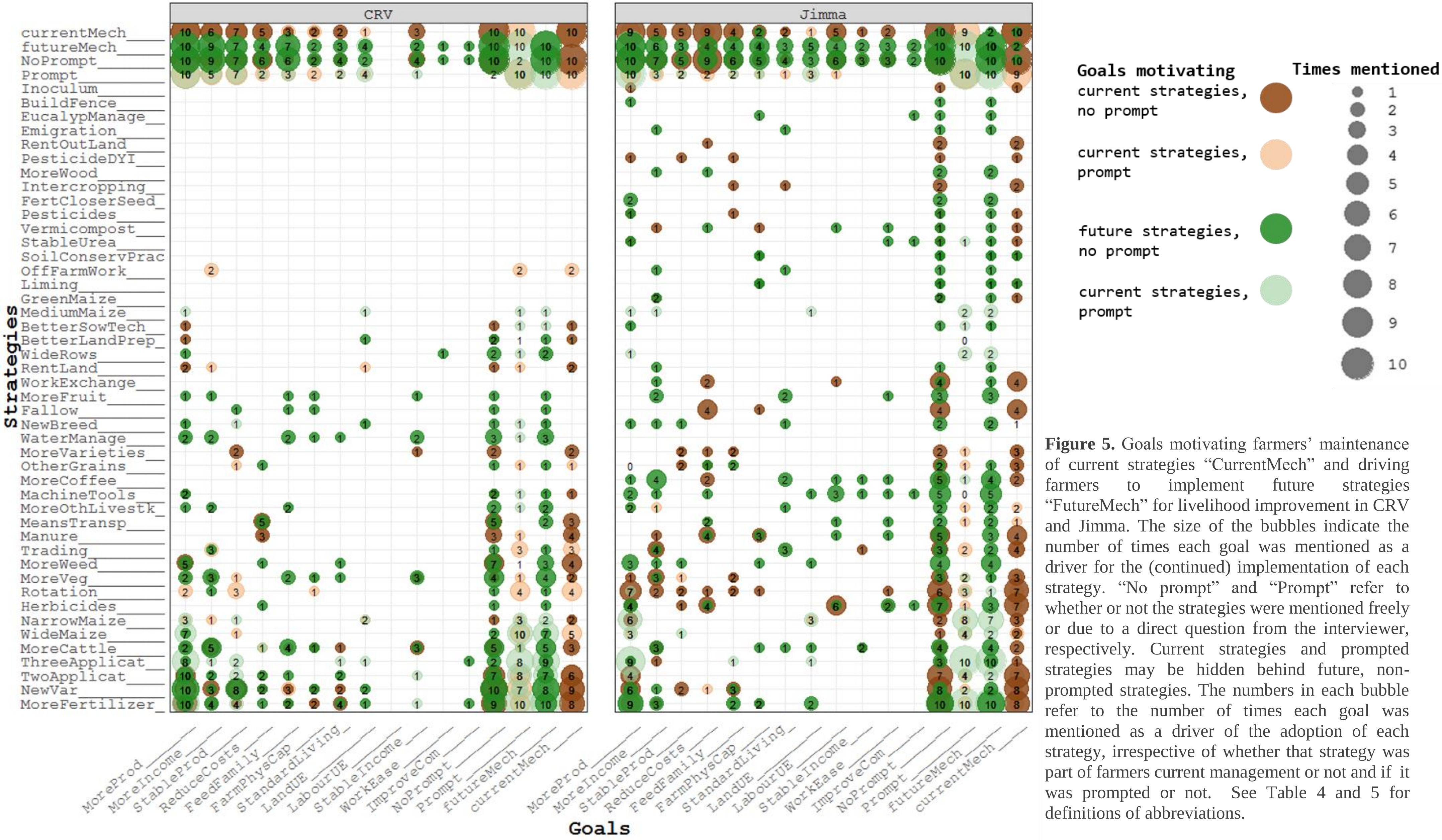


Figure 5. Goals motivating farmers' maintenance of current strategies "CurrentMech" and driving farmers to implement future strategies "FutureMech" for livelihood improvement in CRV and Jimma. The size of the bubbles indicate the number of times each goal was mentioned as a driver for the (continued) implementation of each strategy. "No prompt" and "Prompt" refer to whether or not the strategies were mentioned freely or due to a direct question from the interviewer, respectively. Current strategies and prompted strategies may be hidden behind future, non-prompted strategies. The numbers in each bubble refer to the number of times each goal was mentioned as a driver of the adoption of each strategy, irrespective of whether that strategy was part of farmers current management or not and if it was prompted or not. See Table 4 and 5 for definitions of abbreviations.

3.1.2 Crop strategies

Applying more inorganic fertilizer and **adopting new, improved crop varieties** were mentioned by almost all farmers as strategies both to maintain their livelihood (i.e. they were using more inorganic fertilizer and newer varieties than in the past) and to improve their livelihood in the future (Fig. 6). Most farmers' were motivated to implement these strategies in their maize fields, but there were also farmer that wanted to implement them in other crop sub-systems (e.g. to apply more inorganic fertilizer in their coffee gardens or adopt an improved haricot bean variety). Farmers' motivation for doing so was increasing their production. Additional drivers for applying more inorganic fertilizer and adopting new, improved varieties, respectively, were the desire to improve their living standard and reduce their risk of harvest failure.

Improved **weed management** (by hand, hoe or oxen), was a practice the majority of farmers in CRV and just below half the farmers in Jimma wanted to adopt. Although farmers mentioned several different motivations for doing so, the only motivation shared by the farmers was increasing their whole-farm production and their maize production, specifically. **Application of herbicides** was also mentioned by many farmers, mostly in Jimma (Quote 4). Most farmers that talked about herbicides, however, had already adopted them. Only two farmers who were not already using herbicides reported wanting to apply them in the future. Farmers motivation for using or wanting to start using herbicides was to reduce production costs through a more efficient use of rented labour. Farmers more often applied or wanted to apply herbicides on their teff, peppers and beans than on their maize since the prior crops were more susceptible to weeds and more valuable to farmers. **Improved land preparation** and **application of inoculum** in beans were only mentioned by one farmer each, and were motivated by the prospects of increasing whole-farm production and increase their land use efficiency.

3.1.3 Cropland strategies

Crop rotation was more often already part of farmers' current management than a strategy farmers would like to implement in the future (Fig. 6). The most important motivation for farmers to rotate their crops was to increase their production. Lowering the risk of harvest failure and increasing their income, however, were also mentioned by several farmers. Farmers also talked about wanting to **grow other, more profitable crops** instead of maize, e.g. **vegetables** such as tomatoes and onions, **coffee, fruits** such as avocado and papaya, and **trees** to harvest wood. Their motivation for implementing such land use changes was mainly to increase their income, but ensuring they would get more stable and low-risk income and improving their living standard were also goals mentioned by several farmers (Quote 5). Some farmers also mentioned wanting to **grow other grains**, such as sorghum, millet, and barley, or **leave their land fallow** instead of growing maize to reduce their costs of production due to a lower need for investment in inorganic fertilizer. Farmers also wanted to leave their land fallow, however, because they thought it would improve their soil fertility (part of the goal FarmPhysCap, Fig. 6).

"I want to expand my production of coffee and fruits in order to increase my income to pay for the education, books and uniforms of my children. Actually, I would like to grow coffee and fruits on all my maize fields, but I am faced with financial constraints and furthermore my own kidney problems restrain me from working as hard as I would have liked."

Quote 5, HH3302 (Jimma)

Manure, similar to crop rotation, was more often already part of farmers current management than a strategy that farmers would like to implement in the future (Fig. 6). In Jimma, nevertheless, some farmers were motivated to apply manure on fields that did not receive manure currently (often out-fields) or apply manure at higher rates. Farmers' most common motivation for wanting to apply more manure was to reduce their production costs. Manure, when applied, was used instead of inorganic fertilizer. In Jimma, where farmers perceived the risk of soil fertility loss to be greater than in CRV, maintaining or improving soil fertility was also a common motivation. **Applying lime**, **vermicompost** and **soil conservation practices** such as terracing or planting grass between fields on a slope were also strategies for soil fertility improvement, but were mentioned by only one farmer each. **Intercropping**, also mentioned by only one farmer, was a strategy practiced by the women of the household in order to ensure family food security.

3.1.4 Livestock strategies

Only two strategies influencing the performance of farmers livestock sub-systems were mentioned. **Adopting a new breed of improved livestock** was mentioned by two farmers in Jimma and one farmer in CRV. They wanted to adopt either Holstein Frisian or Boran cattle[2], or improved laying hen breeds. Their motivation for wanting to keep these new breeds was to improve their production and, for cattle, increase their land use efficiency (Quote 6). The farmer with the improved laying hens wanted to **build a fence** to protect them from predators. He preferred this rather than going back to the traditional chickens which were able to scare off or flee from those predators because he wanted to maintain the high number of eggs that the improved hens laid.

"For the future there is no plan to keep the local cow. We have to keep Frisian cow. We want to manage few cattle with better management and feed. And high production."

Quote 6, HH13 (CRV).

3.1.5 Farm strategies

The most common strategy farmers wanted to implement at farm level was **using more of their farm land and/or resources to keep cattle** (Fig. 6). This strategy was mentioned by almost half of the farmers. Their motivation for implementing it was to increase their income and, in CRV, to ensure food security for their families. Some farmers also wished to **keep more chickens, goats and/or sheep**. The motivation for keeping more chickens, goats and/or sheep was similar to farmers motivation for keeping more cattle.

[2] Boran cattle are an East African Zebu beef breed. See FAO (2007) p. 61 for more information.

Water management, which refers to both water harvesting and controlling the amount of water given to crops and livestock (Quote 7), was a practice that three farmers in CRV wanted to adopt to increase production whilst reducing the risk of production failure, and to increase income whilst reducing the risk of income failure. **Investing in tools and/or machinery** was mentioned often in Jimma: half of the farmers wanted to do so in the future. Examples of tools and machinery farmers wanted to have were equipment for weeding or application of herbicides and pesticides, maize milling machines and small tractors, most importantly to increase their income and improve living standards.

I plan to have water harvesting. Water collection. I can collect rain with concrete. So I can collect rainwater and water is not going down into the soil. With this water I want to fatten cattle. I can put it in the field [where the cattle are] or put it here and keep the cattle here. And then also, I want to use this water to plant fruit trees. Around my home.

Quote 7, HH11 (CRV)

A strategy called "Yakuto[3]", **renting (out) land from (to) another farmer**, was mentioned by a few farmers to either reduce their production costs (renting out land) or increase their production (renting land).

3.1.6 Household strategies

Strategies farmers talked about at the level of the household were: trading, investing in means of transport, investing more time in off-farm work, exchanging labour with other farmers and emigrating (Fig. 6). **Trading** was a way for farmers to have an alternative source of income and to improve their living standard. Slightly less than half of the farmers were already doing this, more than the number of farmers who wanted to start doing it in the future. Other strategies such as **getting jobs off-farm** or even **emigrating** were also mentioned (Quote 8), but only by a couple of farmers. **Investing in means of transport** was a common strategy for livelihood maintenance in CRV. It was also a strategy farmers in CRV wanted to continue in the future and a couple of farmers in Jimma wanted to implement. Farmers mere motivated by the prospect of reducing their production costs, i.e. the cost of renting a cart or donkey for transporting harvested crops and/or manure from and/or to the fields.

"I have so poor yield – again this year! It is becoming unmanageable so farmers are trying to go into trade or to emigrate to Saudi Arabia or Sudan"

Quote 8, HH3302 (Jimma)

3.1.7 Strategies as package deals

In some instances, the implementation of two or several strategies had to co-occur in order to fulfil farmers goals (Appendix 7.6). In CRV, for instance, growing fruits and vegetables and – for some farmers – keeping

[3] Yakuto is a traditional practice where the rented land is prepared, planted, weeded and harvested by the renter and the costs of fertilizer and seed, as well as the harvest are shared by the renter and leaser (Kenea, personal communication).

more cattle could not be achieved without an improved water management (Quote 7). In Jimma, applying more manure could not be achieved without a prior investment in means of transportation. In both CRV and Jimma the adoption of new and improved varieties often had to be paired with a higher rate of inorganic fertilizer in order for farmers to achieve their goal of increased production. Similarly, all farmers who wanted to start applying inorganic fertilizer three times also wanted to increase the overall amount of inorganic fertilizer they would apply. In other instances, the parallel implementation of two or several strategies was part of an effort by farmers to create a win-win situation for themselves. Some farmers, for instance, wanted to implement crop rotation and grow more vegetables. By doing this their motivations of increasing maize production and income could be achieved simultaneously.

3.2 Factors influencing the implementation of livelihood improvement strategies

Farmers reported that their implementation of livelihood improvement strategies was influenced by a total of 45 factors. A comprehensive overview of the influence of the most mentioned factors within each factor category follows (3.2.2-3.2.9) after a short overview is presented (3.2.1). In order to enable easy navigation each factor and factor category, when introduced, is bold and underlined. An overview of the influence of all factors on adoption of strategies can be found in Appendix 7.7. In Figure 7, the influence of the factors summarised per factor category (Table 6).

3.2.1 An overview of the factor categories

Farmers' endowment of **financial capital** and farmers' **autonomy** were reported to influence all or all but one farmers' implementation of livelihood improvement strategies in both CRV and Jimma (Fig. 7). **Social capital** enabled 7 farmers in CRV and 5 farmers in Jimma to implement strategies they would not have been able to implement on their own. **Institutional factors** inhibited 8 farmers' implementation of livelihood improvement strategies in Jimma, but only 3 in CRV. 7 farmers in Jimma had insufficient **knowledge and/or skills** to implement strategies they would have liked to implement. In CRV, however, **knowledge and/or skill** was more often reported to positively influence farmers' implementation of future strategies. **Physical** and **human capital** were constraining 5-6 farmers' implementation of future strategies in both CRV and Jimma. **Technological capital** was reported to be influential by less than half of the farmers in both CRV and Jimma.

3.2.2 Autonomy

The most important factors in the category autonomy were farmers' **perception of the relative advantage** of one strategy compared to another or several others, farmers' perception of the risk of implementing or failing to implement a strategy, and farmers' motivation (Fig. 7, appendix 7.7). Farmers' perception of relative advantage was most commonly expressed when they compared narrow and wide planting densities. In CRV most farmers had a negative perception of the relative advantage of planting maize at a narrow density compared to planting maize at a wide density. Some farmers, however, were unsure which density was best (Quote 9). In Jimma the opposite held: farmers perceived a narrow planting density to have a relative advantage over a wide planting density. Two farmers in both CRV and Jimma preferred planting at an intermediate density. Farmers also often expressed their opinion as to whether they thought split fertilizer application had an advantage above baseline fertilization or not. In CRV most farmers perceived split fertilizer application to have a relative advantage over no split fertilizer application (Quote 1), but less than half expressed that they thought three applications was superior to two applications of inorganic fertilizer, and similar to planting density, some farmers were unsure which treatment would be better. Two farmers expressed explicitly that they thought two applications had an advantage over three applications (Quote 2). In Jimma all farmers expressed their preference towards either two or three applications of inorganic fertilizer. Most farmers had a preference for three applications.

"This season, rain was not good. That is disturbing the treatment. The narrow density has also many cobs, but there is the size and the weight that differ. It may be better in the higher density, or it may be better in the lower density. So, that we have to see."

Quote 9, HH13 (CRV)

Farmers' **perception of the risk** of implementing or failing to implement a strategy was also a factor mentioned often. Farmers' perception of risk positively influenced their wish to adopt new, improved varieties in CRV and rotate their crops in Jimma. In both CRV and Jimma growing several different varieties of the same crop was also motivated by a perception of reduced risk. Farmers' perception of the risk of applying more inorganic fertilizer also influenced their decision as to whether to increase their inorganic fertilizer rates or not. Some farmers would rather leave one of their fields fallow than apply lower rates of inorganic fertilizer since they perceived the risk of losing production and income to be lower that way. Other farmers, however, perceived that too high rates of fertilizer to be risky, stating that it would "kill" their fields or "burn" their crops (Quote 2). Farmers' **motivation** positively influenced their perception of strategies that required a lot of effort, such as improved weed management.

3.2.3 Knowledge and skill

Farmers **knowledge** and **skills about strategies** were talked about most in relation to farmers' application of split fertilization (Fig. 7). In CRV most farmers expressed that they knew exactly how and when to apply the inorganic fertilizer. In Jimma, however, farmers' lack of knowledge was constraining their implementation of the practice. Some farmers who expressed that they wanted to adopt a narrow planting density also expressed that they did not know or were unsure about the exact spacing between the maize plants. In addition to having an influence on farmers' ability to adopt researchers' innovations, farmers often expressed that contact with researchers or extension agencies had given them knowledge which made them want to implement strategies such as crop rotation, growing new, improved varieties, keeping more cattle, growing more vegetables or adopting new breeds of livestock (Quote 10).

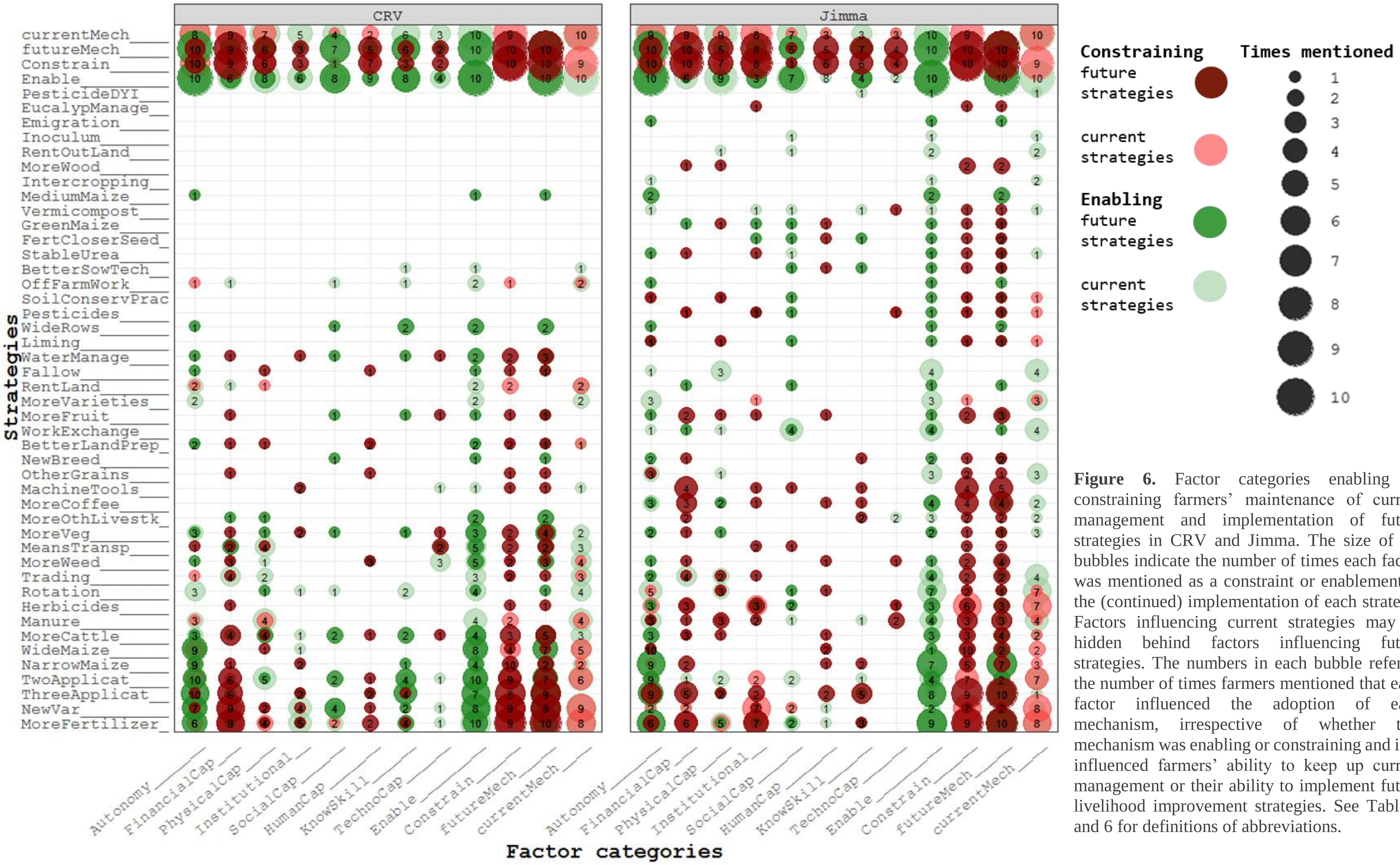


Figure 6. Factor categories enabling or constraining farmers' maintenance of current management and implementation of future strategies in CRV and Jimma. The size of the bubbles indicate the number of times each factor was mentioned as a constraint or enablement to the (continued) implementation of each strategy. Factors influencing current strategies may be hidden behind factors influencing future strategies. The numbers in each bubble refer to the number of times farmers mentioned that each factor influenced the adoption of each mechanism, irrespective of whether that mechanism was enabling or constraining and if it influenced farmers' ability to keep up current management or their ability to implement future livelihood improvement strategies. See Table 5 and 6 for definitions of abbreviations.

"I observed rotation in an experiment and from the rotation they got 15 quintal [of maize] from ¼ hectare and from the field that is not rotated with pepper they got 8 quintal [of maize]. So there is a difference of 7 quintal between rotation and not rotation."

Quote 10, HH7706 (Jimma)

3.2.4 Financial capital

Financial capital, next to autonomy, was the category of factors that most often influenced farmers' abilities to implement future strategies, and it was by far the most important constraining factor (Fig. 7). The most common financial constraint was cash (at the time an investment was needed), influencing the ability of all farmers but one to implement livelihood improvement strategies. Other financial factors, such as off-farm income and access to credit, were only mentioned by a couple of farmers (appendix 7.6).

Financial capital was constraining most farmers' ability to increase their application rate of inorganic fertilizer. Since they wanted to increase the total amount of inorganic fertilizer applied when applying fertilizer thrice instead of once or twice, it was also constraining their ability to adopt split fertilizer application. It was also a constraint on farmers who wanted to keep more cattle (Quote 11). In CRV it was also a constraint to more than half of the farmers' ability to adopt new, improved crop varieties. In Jimma several farmers mentioned that financial constraints hindered them from applying more herbicides, investing in tools and machinery and growing more coffee and fruits. Farmers who were less constrained financially were able to implement strategies, such as trading, renting extra land or investing in means of transportation, which enabled them to acquire off-farm income or save costs of having to rent carts or donkeys.

"A very important activity - it would improve my life - I think, is fattening cattle and selling them to the market. I have seen around this town. The farmers who are doing this are gaining a lot, a lot of money. But I cannot do this right now. I do not have the cash to buy the cattle. And to buy the feed of the cattle. This is my constraint. If I have got a chance, I will concentrate on this."

Quote 11, HH24 (CRV)

3.2.5 Human capital

Human capital was mentioned by more than half of the farmers as a factor influencing their ability to adopt livelihood improvement strategies. Yet, it was not a constraint that influenced the implementation of any specific strategies in particular. **Labour**, the most common human factor, was not often reported to be constraining. Farmers did not have enough household members to perform all their agricultural activities, yet there was a large labour force available in both CRV and Jimma. The farmers were, however, not able to pay for this labour. Hence it was not labour but farmers' lack of capital that was talked about most of the time. Nevertheless, some farmers did not see renting labour an option at all.

These farmers perceived the limited number of **family members** in the household to be constraining to their ability to, for instance, improve their weed management. Other farmers mentioned that they could not, for instance, apply more inorganic fertilizer, keep more cattle or grow green maize (which was sold to an urban market as street food for a higher price), because the money or land needed to implement these strategies was needed to educate or feed their families (Quote 12).

3.2.6 Physical capital

Livestock and land were the most important types of physical capital influencing farmers ability to implement livelihood improvement strategies. **Livestock** were a common enabling factor expressed in relation to split fertilizer application since farmers would weed the maize inter-rows by oxen in the seedling stage - they referred to this practice as Shilshalo[4] - before they applied the second split of inorganic fertilizer. Farmers who did not practice Shilshalo[4] did not apply inorganic fertilizer in split either. Farmers' ownership of **land** mainly influenced whether or not they were able to implement crop rotation, leave their land fallow, grow cash crops and keep more cattle. Farmers reporting that land was a constraint to the implementation of these strategies, thought all (or most of) their land was needed to grow maize because growing less maize would make them (more) food insecure (Quote 12).

3.2.7 Social capital

Very few farmers expressed that they were constrained by social capital, but many mentioned that their social relationships were enabling their implementation of livelihood improvement strategies. Farmers' relationships with researchers or other farmers were most important. **Contact with researchers**, as was mentioned in relation to farmers' knowledge, enabled farmers to implement strategies such as crop rotation, growing new, improved varieties, keeping more cattle, growing more vegetables or adopting new breeds of livestock (Quote 10). Farmers' **relationship with other farmers** helped them implement this knowledge in practice (Quote 1). In Jimma, Yakuto[3] also enabled farmers to implement strategies such as for example applying more inorganic fertilizer, preparing the soil better and growing green maize (Quote 12). Some farmers also benefitted from having **relatives** which helped them to buy inputs such as inorganic fertilizer and improved seeds.

"I do not want to expand the green maize or the cattle fattening too much because I do not have enough land for that. I need that land to feed my family. But I would like to rent extra land to grow green maize via Yakuto[3]. I am already doing Yakuto[3] for another crop this year and will do it for green maize next year."

Quote 12, HH5003 (Jimma)

[4] This is a traditional Ethiopian sorghum and maize cultivation practice. See Desta (2000) for more information.

3.2.8 Technological capital

Technological capital was not a commonly mentioned factor influencing farmers' implementation of livelihood improvement strategies, but it was very important for the farmers who did mention it. A few farmers expressed that not having a **cart or wheelbarrow** hindered them from applying more manure to their fields. Other farmers expressed that having **tools** enabled them to improve their weed management. **Fences**, building material such as **cement** (for water harvesting) and **livestock housing** were mentioned as factors constraining or enabling expansion of farmers' livestock production systems.

3.2.9 Institutional factors

Institutional factors influenced most farmers in Jimma, but only a few farmers in CRV. In Jimma, many farmers expressed that the regional **supply of farm inputs** such as inorganic fertilizer, improved seeds and herbicides and pesticides was too limited and often arrived too late. They also told us that the **quality of** these **inputs** was poor. This hindered them from implementing new technologies and sometimes caused farmers to dis-adopt, for instance, a new, improved variety. Farmers who had learned about new technologies through their work with researchers were especially frustrated by this (Quote 13).

"There is a variety called quality maize protein [QPM[5]]. I was doing with one researcher, but after the research was completed, there was no one who was responsible to bring that variety to the farmer. Agricultural offices do not bring that one. This variety is very important for children. It is full of protein. […] But I cannot currently get access to that maize. I have saved some seeds so far and just at the border of our experiment I have planted. That plant has almost 2 cobs for every plant. That has high yield. So I want to gain more seeds. Some company come and make research and after that the agricultural people do not come and bring that variety. That is a challenge."

Quote 13, HH4801 (Jimma)

In addition to input-related institutional constraints, many farmers complained about the performance of the local agricultural extension services. They did, however, not give many examples of how this influenced their ability to implement livelihood improvement strategies. One farmer, however, told us that the extension services had failed to supply avocado seedlings reserved for farmers because they had been corrupted by better offers from people living in the city. Another farmer told us that the lack of regulations concerning eucalyptus cultivation was a cause of conflict in the community because it made neighbouring fields unsuitable for water-demanding crops.

[5] QPM or quality protein maize is a bio-fortified maize variety that has been promoted in many regions in Ethiopia, including Jimma, but not CRV as far as we know. See de Groote et al. (2016) for more information. At the moment, however, the supply of QPM seed in Jimma is limited due to problems in the seed multiplication company (Kenea, personal communication).

3.2.10 Factors influencing farmers' current management

Most of the factors influencing farmers' ability to implement strategies for future livelihood improvement, were also affecting farmers' ability to maintain their current management (Fig. 7). Institutional factors (in CRV), knowledge (in Jimma) and technological capital (in CRV), enabled some farmers' to maintain their current management, but were constraining to other farmers' future implementation of similar strategies. Some factors were more important for farmers' future management than for their current management. Farmers' perception of risk, for instance, was more commonly expressed as reason for farmers' current management decisions than as a reason for farmers' future management preferences (in Jimma).

3.3 Comparisons of researchers' innovations and other strategies

In this section farmers' perceptions of the relative performance of researchers' innovations compared to farmers' baseline management and the relative suitability of researchers' innovations compared to other livelihood improvement strategies are presented. A comprehensive overview of the regional adoption potential of the various strategies, and the constraints hindering their implementation will also be presented.

3.3.1 The perceived relative performance of researchers' innovations

Farmers perceived a high planting density (NarrowMaize) and a high fertilizer rate (MoreFertilizer) to perform significantly better ($p < 0.05$) than their baseline management (Fig. 8A, WideMaize and BaseFertilizer). Farmers did, however, not perceive three applications of inorganic fertilizer to be superior (or inferior) to two applications of inorganic fertilizer (Fig. 8A). The four performance criteria given the highest importance rankings, profit, yield, grain weight and cob number, did not differ significantly from each other. Cob size was of intermediate importance: significantly more important than the latter criteria, but significantly less important than the most important criterion. Resistance, air circulation and colour (Table 6) were of significant lower importance than the other criteria used to weigh the relative performance of farmers baseline management and researchers' innovations (Fig. 8B).

Visual analysis showed that the performance perceptions of all farmers in Jimma and the majority of farmers in CRV were positively correlated to the actual yields that were obtained in their on-farm trials (Fig. 9). In CRV, where differences in yield were generally small, 4 out of 10 farmers' performance perception were negatively correlated to obtained yield.

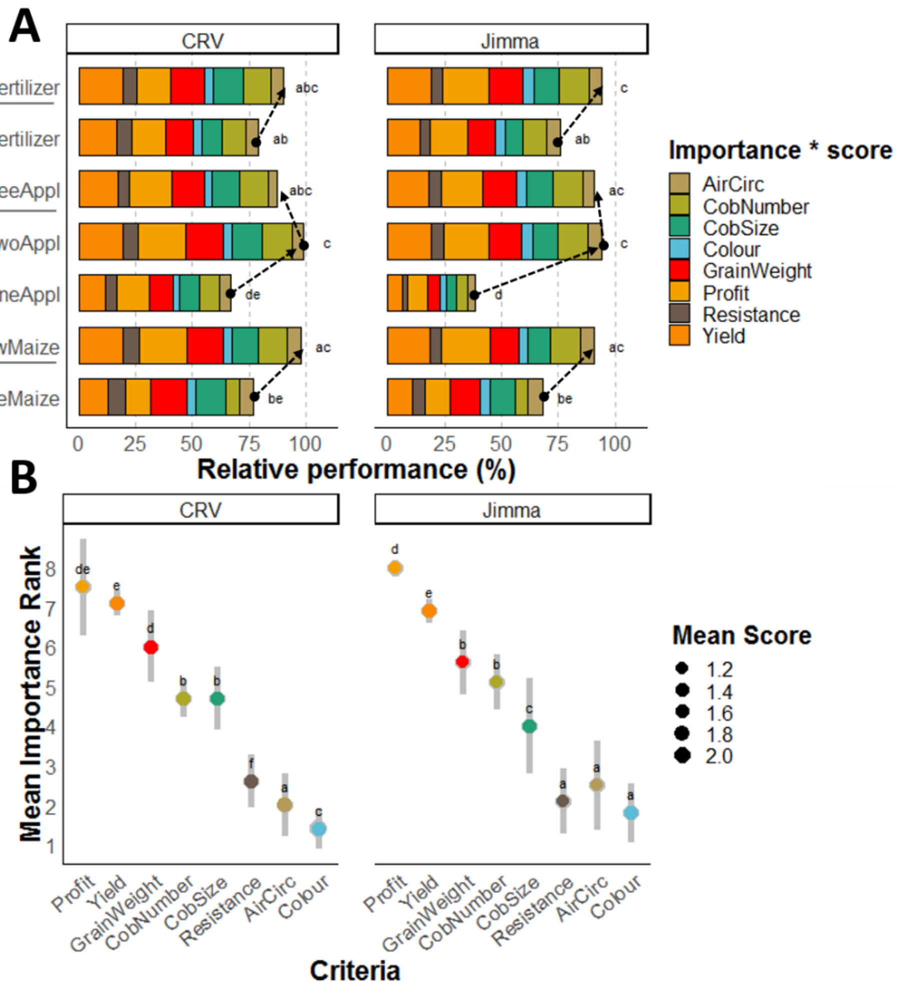


Figure 8. A: Relative performance of researchers' innovations (Morefertilizer, NarrowMaize and ThreeAppl), farmers baseline management (BaseFertlizer, TwoAppl or OneAppl and WideMaize). The size of each colour in the stacked bars give the relative performance (importance * score) of the baselines and innovations in accordance with one of the criteria. **B:** The mean importance ranks and scores attributed to performance criteria. The grey error bars show the standard deviation of the average rankings. **Both**: the letters (a-e) indicate whether the relative performances and importance ranks differ significantly ($p < 0.05$) from each other (no letter(s) in common = significant difference).

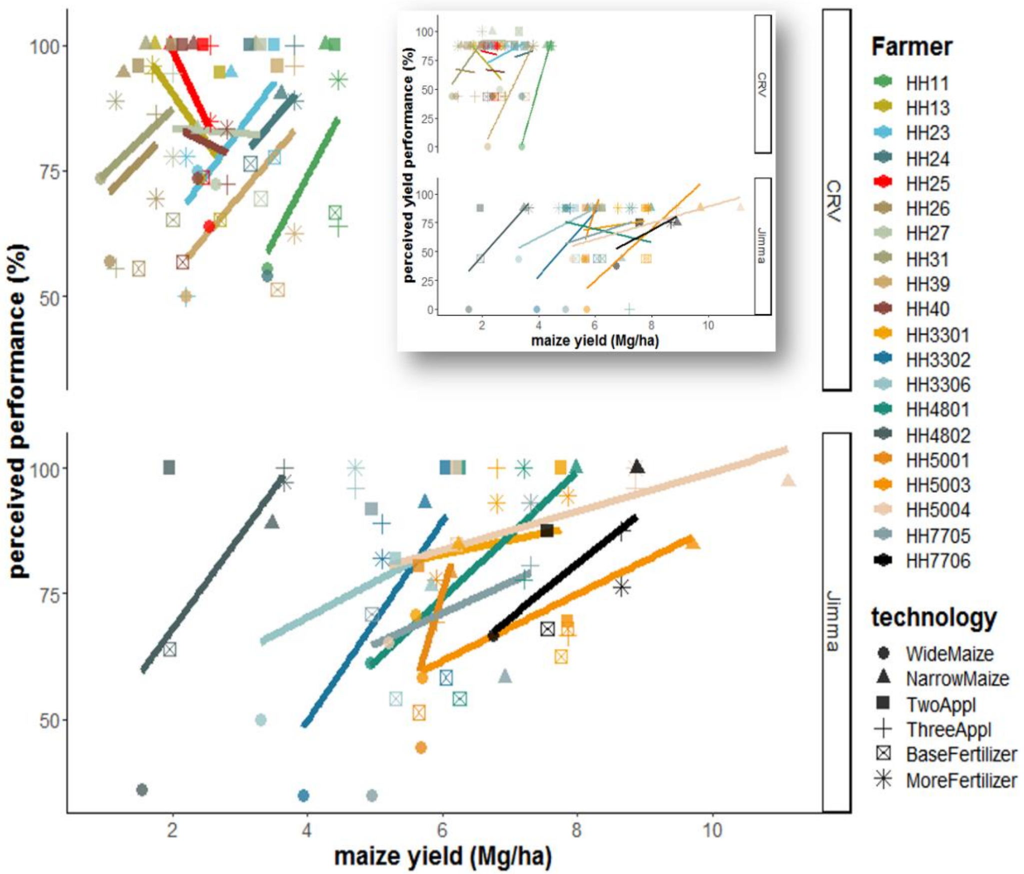


Figure 9. Farmers' perceptions of the relative performance of researchers' innovations and their baseline management plotted against farmers' actual maize yields (Mg/ha). **Upper corner:** Farmers relative perceived yield performances plotted against farmers' actual maize yields (Mg/ha). **Both:** The lines show the linear relationship between the actual yields and the perceptions of each interviewed farmers.

3.3.2 Relative advantage of researchers' innovations

Farmers reported that ensuring family food security and improving household standard of living were the most important goals, followed by increasing household income, increasing production, reducing production costs and increasing land use efficiency, increasing financial security and reducing the risk of harvest failure (Fig. 10 B). The average relative advantage of livelihood improvement strategies according to those goals ranged from ~25% to 100% (Fig. 10A), where 100% means that all farmers agreed that a strategy contributed to all livelihood improvement goals. Farmers' perceptions of relative advantage were different in the two different regions. In CRV, crop rotation, new, improved varieties, keeping more cattle, growing more vegetables and investing in means of transportation were perceived to have a significantly higher ($p < 0.05$) relative advantage than investment in tools and machinery, higher rates of inorganic fertilizer and a wide maize planting density. A narrow maize planting density, three inorganic fertilizer applications and improved weed management were perceived to have an intermediate relative advantage. In Jimma, differences in farmers' perception of the relative advantage of livelihood improvement strategies were less distinct. Rotation was rated to have the highest relative advantage, but differed significantly only from the five strategies given the lowest relative advantage ratings, improved weed management, investment in means of transport or tools and machinery, application of higher rates of inorganic fertilizer and a wide maize planting density. The other strategies did not differ significantly from each other or from any other strategies except for crop rotation, investment in tools and machinery, higher rates of fertilizer and, in some cases, improved weeding.

3.3.3 Factors hindering implementation of researchers' innovations and other strategies

The factors constraining implementation of strategies differed among the strategies (Fig. 11). The most frequent constraint was cash. This constraint, in contrast to other constraints, affected farmers' ability to implement almost every strategy. For some strategies, such as investment in tools and machinery and more cattle, all farmers who had not implemented the strategies yet were hindered from doing so due to their lack of financial capital. Labour was the second most important constraint. It inhibited farmers from investing in tools and machinery and means of transportation, application of higher rates of fertilizer, improved weed management, growing more vegetables or coffee, implementing crop rotation and planting maize at a regular, narrow density.

After labour, the constraint that was inhibiting to most farmers was "unknown". This constraint was noted down when farmers' said they did not want to implement a strategy, but did not give a reason for why they did not want to do so (Fig. 11). What inhibits farmers from not applying higher rates of inorganic fertilizer, three applications of inorganic fertilizer, improving their weed management and increasing their maize planting density is, therefore, partially unknown. Further, some farmers reported not having enough knowledge to invest in tools and machinery, more cattle or more coffee and a few farmers reported that their limited ownership of land hindered them from keeping more cattle and implementing crop rotation. Input quality and availability were not reported to be constraining in CRV, and only to constrain a few farmers in Jimma from applying of inorganic fertilizer three times and at higher rates (Fig. 11).

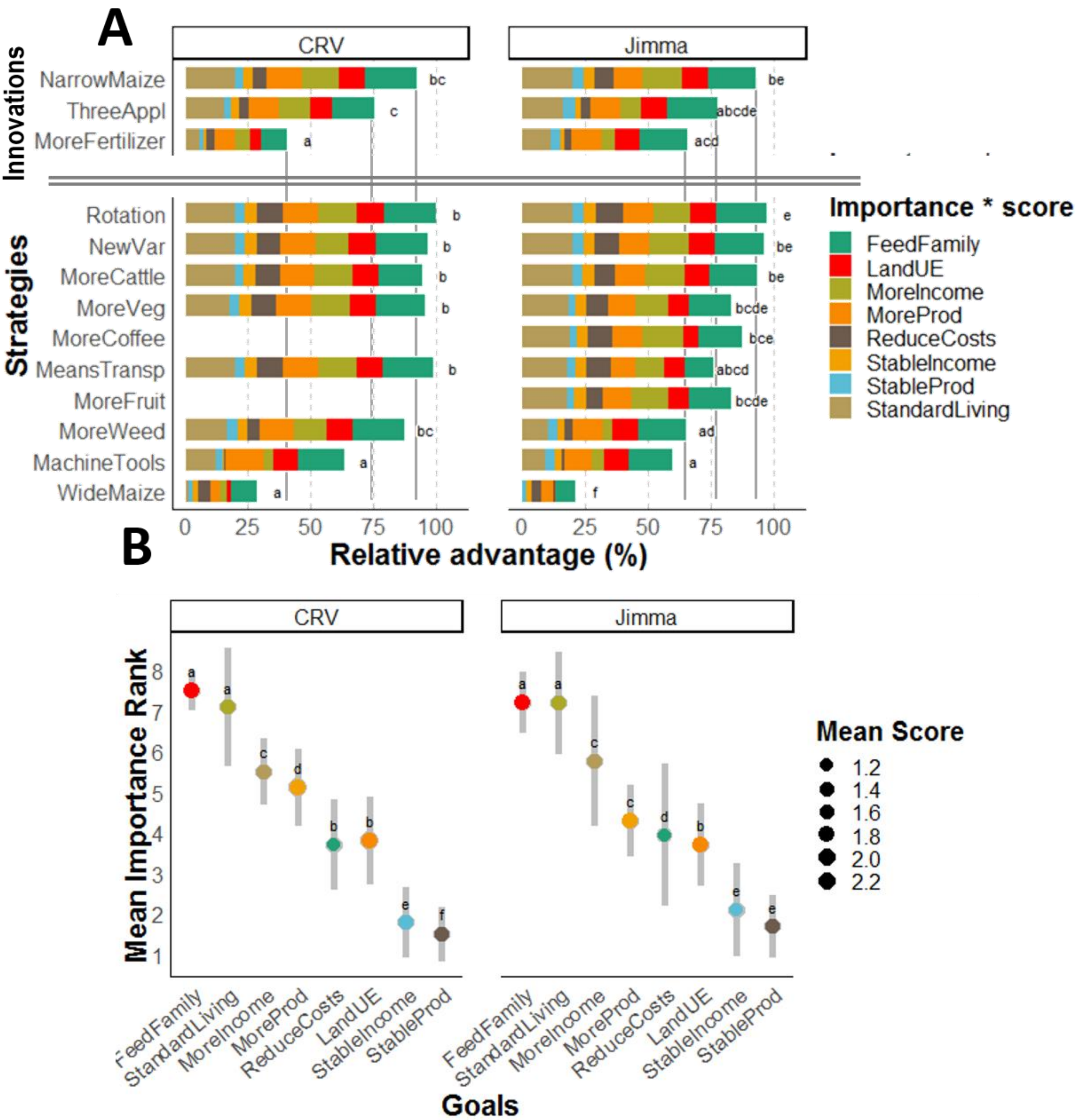


Figure 10. A: The average relative advantage of researchers' innovations compared to other livelihood improvement strategies. **B:** The average importance of goals and the average scores of goals. The line range gives the standard deviation of the importance rating. **Both**: the letters (a-e) indicate whether the relative advantages and importance ranks differ significantly ($p < 0.05$) from each other (no letter(s) in common = significant difference). See Tables 4 and 5 for abbreviations.

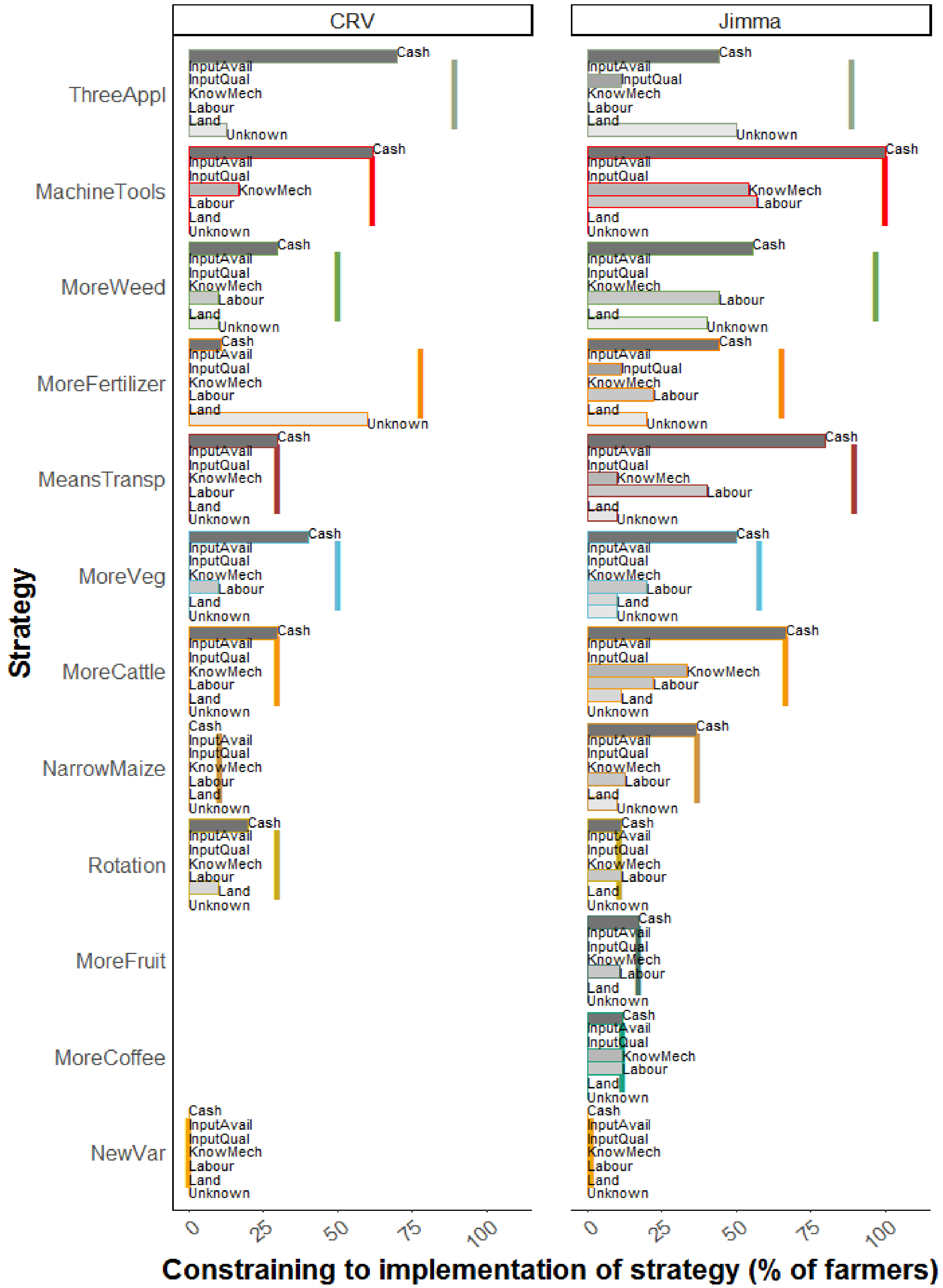


Figure 11. The % of farmers in CRV or Jimma whose implementation of a strategy was constrained by cash, input availability, input quality, knowledge, labour, land or an unknown constraint (equation 3). The vertical, coloured lines show the adoption gap for each strategy (equation 2). See Tables 6 and 7 for abbreviations.

4 Discussion

This study identified farmers' goals for livelihood improvement, farmers' strategies for achieving those goals, the criteria farmers used to evaluate whether researchers' innovations were superior to their baseline management, and the constraints inhibiting farmers' implementation of livelihood improvement strategies, including researchers' innovations. Data were collected in two steps. In step 1 a wide range of different goals, criteria, strategies, and constraining and enabling factors were identified. In step 2, a comprehensive and weighted assessment was made for a selection of these so that strategies could be compared to farmers' baseline management, and to each other based on their relative performances and relative advantages, respectively. On the basis of these results, we revisit researchers' innovations, discussing whether their adoption is likely and what aspects of the innovations might need to be adapted to increase the likelihood of adoption. We also discuss which strategies, besides researchers' innovations, are fit for improving farmers' livelihoods, the goals that drive farmers' wish to implement them, and the constraints that inhibit them from doing so. Finally, we reflect on the implications the findings of this study have on R4D in Ethiopia at large.

4.1 Researchers' innovations revisited

4.1.1 Three applications of inorganic fertilizer

Our results showed that three applications of inorganic fertilizer was perceived to have an intermediate relative advantage (Fig. 10), but was not perceived to be superior to two applications of inorganic fertilizer (Fig. 8), which was the most common baseline practice among farmers. In CRV farmers' performance perceptions were in line with the outcome of the experimental trials where the yields obtained from two and three applications of inorganic fertilizer were indeed not different (Fig. 5; Quote 2). As indicated by Getnet et al. (2016), improving other aspects of farmers' management, such as their rain water management, might be necessary to increase nutrient use efficiency to a sufficient level where the effect of an additional fertilizer applications would be visible. In Jimma farmers' performance perceptions were not in line with the outcome of the experimental trials where application of inorganic fertilizer thrice instead of twice increased farmers' yields by 1.6 tonnes ha^{-1} on average (Fig. 5). The fact that farmers were only asked whether they "disagreed", "partially agreed" or "agreed" that two or three applications of inorganic fertilizer performed well according to their performance criteria, is likely to have masked some of the differences in perceptions that farmers' may have had. Farmers generally agreed that both two and three applications performed well according to most performance criteria (Fig. 8). Using Likert-type scales (Likert, 1932) in which farmers could indicate extreme degrees of (dis)agreement, as well neutral opinions and uncertainty, would most likely reveal greater differences in perceived performance. In general, this would improve the predictive ability of this research by capturing farmers opinions more accurately. Asking farmers how strongly they felt about their responses in accordance with a two-stage Likert-type scale (Albaum, 2018) could improve the predictive ability even further.

4.1.2 Higher rates of inorganic fertilizer

Application of higher rates of inorganic fertilizer was perceived to be superior to farmers baseline rates of inorganic fertilizer in both CRV and Jimma (Fig. 8). In CRV, however it was perceived to be a less advantageous strategy for fulfilling farmers' goals than all other strategies that were assessed except for a wide planting density (Fig. 10). In Jimma it was perceived to have an intermediate relative advantage (Fig. 10). The regional difference between the perceived advantage of application of higher rates of fertilizer is most likely caused by the fact that the effect of increased rates of inorganic fertilizer are low in CRV (Fig. 5). As mentioned previously, improving farmers current rain water management might be necessary in order for increased rates of fertilizer to have an effect (Quote 2; Getnet et al., 2016). In Jimma, where farmers perceptions of the relative advantage of applying higher rates of inorganic fertilizer was found to be less likely to be limiting adoption than in CRV (Fig. 10), financial constraints, labour constraints and the poor quality of the inorganic fertilizers posed a challenge. Addressing this challenge requires innovation at community-level and regional levels as well as at farm level (Getnet and MacAlister, 2012; Schut et al., 2016).

4.1.3 Increased planting density

Farmers perceived increased planting density to have an intermediate relative advantage (Fig. 10A) and to perform better than their baseline (wide) planting density (Fig. 8A). When asked whether they wanted to increase their planting density in the future, however, almost all farmers in CRV said they had already increased their planting density enough (Fig. 11). In Jimma only 4 farmers showed interest in increasing their planting density. Given the relatively high advantage farmers' attributed to this strategy, the low number of farmers that reported wanting to increase their planting density is surprising. An explanation to this may lie in farmers' uncertainty regarding the benefits that can be achieved by increasing planting density. Empirical studies (Marra et al., 2003) have shown that strategies with high risks and uncertainty may be subject to limited adoption, depending on the potential users of the strategies. We find it unlikely that risk could explain the low interest in the a narrow planting density since farmers attached little importance to the goals of reducing the risk of production and income failure (Fig. 10B). That farmers often expressed uncertainty about the benefit that could be achieved from increasing planting density, however, this may (partially) explain their hesitance towards adapting their current planting density (Quote 9). According to Rogers (2003), this would mean that most farmers have not yet entered into innovation-decision processes: despite being exposed to the innovation, they have not yet been inspired to find out more about it. In both CRV and Jimma, however, some farmers already talked about starting their own planting density experiments (Quote 3). This suggests that some farmers will overcome their uncertainty and thereby either be persuaded to increase their planting density or to maintain their baseline density. Our experimental trials suggest that the prior will likely happen in Jimma (where yields increased by 1.2 tonnes ha^{-1} on average; Fig. 5) and the latter will happen in CRV (where yields did not increase; Fig. 5). Farmers persuaded by their acquired knowledge may contribute to the diffusion of the innovation to other farmers (Rogers, 2003).

4.2 Farmers' goals, constraints and livelihood improvement strategies

4.2.1 Farmers' goals for livelihood improvement

This study showed that many different types of goals underlie farmers' aspirations for livelihood improvement, guiding farmers' management decisions (Fig. 6). In the step 1 interviews the number of farmers mentioning each goals varied per region. In CRV most farmers mentioned reducing the risk of harvest failure and ensuring household food security as drivers for their implementation of changes to their current farm management, compared to only about third of the farmers in Jimma. The emphasis on these goals in CRV makes sense since farmers there were subject to irregular rainfall and recurrent droughts and had larger families (Kassie et al., 2014). In Jimma, where households were generally smaller than in CRV, farmers motivation to implement livelihood improvement strategies were more diverse and labour use efficiency was mentioned much more than in CRV. That being said, in step 2 farmers' importance rankings of the selected goals did not differ much between the regions. For both regions, ensuring household food security and improving household standard of living were ranked most important despite not being mentioned so often in step 1 (Fig. 6).

An induced response bias towards improving production in step 1 may be the reason for this apparent discrepancy since farmers reported that their previous experiences with researchers had been production-focussed (Quote 10). Additionally, a Kenyan case study that researched farmers' goal hierarchies suggests that increasing production is not a goal in itself, but a means for farmers to reach the more deep-seated goals such as ensuring household food security and improving household standard of living (Fig. 10, Okello et al., 2019). Increasing production, as well as increasing income, and stabilizing yields and incomes are then what in consumer science are called operational goals (referred to as sub-goals, enabling consumers to realise deep-seated goals) and are considered to be nested within those deep-seated goals (Gutman, 1997). The importance of these deep-seated goals in step 1 may have been overlooked because the interviewer did not make the interviewees go beyond these superficial and operational goals. This implies that the importance of deep-seated goals may have been underestimated in step 1. In step 2, the method used for quantification of relative advantage might in theory have induced a bias towards strategies contributing to the deep-seated goal with the most sub-goals since the relative advantage was calculated as the weighted sum of the sub-goals and the deep-seated goals themselves. In this case study, however, we do not find it likely that this caused a biased result since all sub-goals could – in theory – contribute to both of the deep-seated goals, family food security and an improved living standard.

4.2.2 Farmers' livelihood improvement strategies

This study revealed that farmers knew about and desired to implement a multitude of livelihood improvement strategies. The strategies that most farmers talked about, higher rates of inorganic fertilizer and new varieties, were mainly strategies to improve the performance of their maize cropping systems (Fig. 6). Farmers did, however, also talk about many different strategies that would change the performance of their entire cropland or farms. Many of these strategies related to a transition towards less maize cultivation and more production higher-value (or lower-cost) commodities (Fig. 6). Although few farmers mentioned the link between maize productivity and arable land available for production of high-value commodities explicitly, it is likely that farmers will not maintain the current size of their maize area if they adopt innovations that improve their maize yields since maize is mainly produced for household consumption and not marketed as it has low and very variable profit margins (Gabriel and Hundie, 2006; Rashid et al., 2010). Crop rotation, which was the strategy that was perceived to have the highest advantage in accordance to farmers' goals (Fig. 10A) would be a way for farmers to increase their maize productivity and grow high-value crops (Quote 10). Research done in agroecologies similar to CRV and Jimma found that crop rotation could increase maize yields by ~1.9 tonnes ha^{-1} (Mashingaidze et al., 2017) and ~1.1 tonnes ha^{-1} (Abera et al., 2011), respectively.

When asked to evaluate the potential of strategies to contribute to their eight most important goals for livelihood improvement, farmers in CRV answered that all selected strategies but application of inorganic fertilizer thrice and at higher rates, investment in machinery or tools, and a decreased planting density had a relatively high advantage. In Jimma, however, the only strategy that would clearly not enable farmers to realise their goals was a decreased planting density. The lack of significant differences between the other strategies with relatively high advantages might, as discussed in 4.1, be due to the fact that farmers could only express whether they "disagreed", "partially agreed" or "agreed" that the strategies contributed to their goals. Investment in machinery and tools may be less advantageous in CRV because fewer farmers found labour use efficiency important (Fig. 6), and strategies aimed at improving nutrient use efficiency are likely to be perceived to be less advantageous for the same reasons as discussed in 4.1 (Getnet et al., 2016).

Despite the low relative advantage score application of higher rates of inorganic fertilizer got in step 2 in CRV, it was a strategy mentioned by all farmers' in step 1. It is possible that the livelihood improvement potential of this strategy may have been over-emphasized by the farmers in the step 1, because the farmers hoped that in doing so, they would receive support from us or our organizations (Helmes et al., 2015). Even though the translator did not translate any statements that would suggest this was the case, he told me off-record that farmers' had told him explicitly that they thought we were going to deliver them aid (Kenea, personal communication). After it became apparent to them that they would not receive support as a direct effect of the interviews, i.e. in the second round of interviews, they may have answered more honestly and therefore assessed higher rates of inorganic fertilizer to have a relatively low advantage (Fig. 10).

Adoption of herbicides and keeping smaller types of livestock such as chickens, goats and sheep were future strategies that were mentioned non-prompted by four farmers in total (Fig. 6, appendix 7.8), yet they were not considered in step 2 because we failed to recognize their importance prior to the step 2 interviews. This happened due to a pressure on quick analysis since the interviews should be held soon after the harvest season so farmers still had the outcomes of the experimental trials fresh in mind. It would have been interesting to know how advantageous farmers perceived these strategies to be since herbicides was a strategy that farmers recognized would enable them to save labour whilst maintaining a high production and keeping smaller livestock had similar advantages as keeping cattle but required less investments and maintenance (Descheemaeker et al., 2016). To avoid that strategies are overlooked in future studies, interview transcription and coding should be performed by teams of researchers instead of individual researchers. This would also contribute to enhancing qualitative vigour (Chandra and Shang, 2017).

4.2.3 Factors affecting farmers' implementation of livelihood improvement strategies

Farmers' ability to implement livelihood improvement strategies were found to be subject to a wide range of regional institutional factors and factors related to farmers' resource endowment and skills, knowledge and perceptions (Fig. 7). Apart from financial constraints, which were the most important in both CRV and Jimma, the presence of most enabling and constraining factors differed between the regions (appendix 7.7). Institutional constraints, for instance, were uncommon in CRV but mentioned by most farmers in Jimma. In general, however, farmers' in CRV reported being less constrained than farmers in Jimma (Fig. 7, Fig. 11). This finding was surprising since households in CRV generally had a lower per capita resource endowment. The finding is, however, in line with Maslow's (1943) theory of human motivation. Since it was harder for farmers' in CRV to meet their physiological needs, they were probably less concerned with factors constraining them from improving their need for, for instance, quality leisure time (Ruben et al., 2006). This distinction between the regions is also reflected in how often farmers talked about the goal of increasing food security in CRV versus improving labour use efficiency and work ease in Jimma (Fig. 7).

The number of farmers' mentioning being constrained by a lack of technological capital was lower than might have been expected given that the national technological maize yield gap has been estimated to be about the same size as the economic maize yield gap (Assefa et al., 2017). The fact that technological capital was more often perceived to be constraining in Jimma where households were endowed with more resources and farmers were more concerned with labour use efficiency and work ease, may however be an indication that technological constraints may become more apparent to farmers once their most critical economic constraints are alleviated. This also follows from Maslow (1943).

When we made a comprehensive overview over the influence of the most important factors constraining farmers' implementation of future strategies, it was obvious that cash was the major constraint in both CRV and Jimma, and hindered farmers' implementation of all livelihood improvement strategies. Labour and knowledge, however, were also found to be important; more important than expected from the step 1 interviews (Fig. 7, Fig. 11). There were, in fact, large labour forces available in both CRV and Jimma. Farmers were, however, not able to pay for this labour because they were financially constrained. The financial constraint, therefore, was probably more on the foreground in farmers minds, and therefore mentioned more often in response to open questions. The underestimation of the number of famers which were constrained by knowledge, may have been due to the fact that farmers' were confronted and asked about strategies in step 2 that they – in many cases – had not talked about in step 1. The reason why these strategies were not mentioned in response to open questions, may have been that farmers did not perceive them to be options due to their lack of knowledge. If farmers only mentioned strategies that they had knowledge about in step 1, that would explain why knowledge appeared to be a less important constraint based on those interviews.

To address the gaps in farmers' knowledge, policies facilitating the creation of community-level support networks for (and by) farmers wanting to invest in mechanisation, means of transportation, water management, coffee and fruit production, or more intensive livestock farming could be developed (Scoones and Thompson, 2009). In order to address farmers financial constraints, these networks could be expanded to cooperatives in which farmers share investment costs and physical capital or credit delivery systems. Farmers' dual financial and land constraints could be addressed through legalization and encouragement of land exchange and group farming (Ketema and Bauer, 2011).

Input availability and quality were found to be less important constraints in the step 2 interviews than in the step 1 interviews. The difference between the two steps could be caused by the way in which the questions were phrased in step 2. For instance, it seems to be the case that farmers were asked whether they wanted to adopt improved crop varieties. In response to that question, all farmers reported that they had already adopted improved varieties. While this is in line with the findings from step 1, most farmers had not adopted the newest and best improved varieties. If more emphasis had been put on *new*, improved varieties, fewer farmers would likely have reported that they already had adopted them and therefore it might have become apparent that these new varieties were not available. Another explanation for the low rates of farmers who reported being constrained by the availability of good quality inputs could be that farmers were only occasionally asked why they did not want to adopt a strategy, when they answered not wanting to do so. For instance, many farmers reported not wanting to apply inorganic fertilizer three times. The "unknown" constraint, therefore, was substantial. It is possible that farmers, if asked, would have said that they did not want to apply fertilizer three times due to their lack of access to good quality inputs.

In this study, only constraining factors were considered in step 2. It would, however, be valuable to explore enabling factors as well since this would provide more insight into what strategies farmers would be likely to implement if they were less constrained. In order to do so, farmers could be asked whether factors either "enabled them", "inhibited them from" or "did not affect their" implementation of livelihood strategies. This would also improve the predictive ability of the research and, as mentioned previously, farmers could be asked how strongly they feel about their response in accordance with a two-stage Likert-type scale (Albaum, 2018). Another limitation of this study was that only the absence or presence of constraints and not the relative importance or intensity of constraints was considered. Additionally, this study provided no information about whether alleviating a single constraint would help farmers to overcome other constraints, or if constraints would have to be alleviated simultaneously, i.e. whether implementation of new strategies would be proportional to the alleviation of one or a few constraints, or of the most limiting constraint[6]. Disconfirmatory assessment interviews (Andersen et al., 2012) could be performed to assess the importance of the interacting constraints.

To address institutional constraints such as poor access to inputs at the time that they are needed and with the quality required, policies strengthening the Agricultural Input Supply Enterprise, the various seed suppliers and the cooperative unions (Schut et al., 2016; Spielman et al., 2011) could be developed. Inputs would, however, need to be profitable since all but one farmer reported being constrained financially. Our research found that many farmers did not currently perceive their maize production to be profitable, and that maize area was limited to the minimum needed to ensure food self-sufficiency. From a national perspective, this means that maize food self-sufficiency in the face of population growth cannot be maintained without improvement of the maize supply chain (Rashid et al., 2010) and/or macroeconomic policies incentivising maize production (Barrett, 2008). An alternative national approach could be to

[6] In agro-ecology this is referred to as Liebig's law of the minimum. Liebig's law has been applied to many other disciplines than agro-ecology (Gorban et al., 2011), but not to adoption research, as far as I am aware.

facilitate the transition from maize to cash crops and livestock, but this would imply shifting the current food self-sufficiency narrative (Abate et al., 2015; Spielman et al., 2011) to a food security narrative in which trade co-dependency is embraced. In this narrative, productivity enhancing innovations could contribute by increasing maize productivity and thereby freeing land for production of cash crops and livestock (McArthur and McCord, 2017).

4.3 Implications for agricultural R&D in Ethiopia

Prior to this study, research on adoption of agricultural innovations in Ethiopian smallholder systems growing maize (e.g. Asrat and Simane, 2017; Appendix 7.1) was all based on household surveys and econometric modelling. The findings discussed above provide two valuable new insights into questions that these studies have not been able to address. Firstly, this study gave insight into why farmers may (not) want to adopt new strategies. It did so by identifying the goals driving farmers to adopt new types of farm management and showed that farmers ultimately consider the impact that adoption will have on the food security and living standard of their households (Fig. 10B). These goals may be achieved through either agronomic maize innovations or management changes at cropland or farm level, but a combination of the two would be preferable as it would enable farmers to maintain their maize food security whilst improving their living standard through production of higher-value commodities (McArthur and McCord, 2017).

Secondly, this study gave insight into how farmers think about and compare different strategies. It revealed that farmers were aware of and motivated to implement a large number of livelihood improvement strategies. Some of these strategies, such as investment in means of transportation, tools and machinery, herbicides, crop rotation, and improved weed management, have not yet been researched (Appendix 7.1), yet were perceived to contribute to many of farmers goals for livelihood improvement. An important realisation that stems from this study, and has been indicated by other studies that also researched several different strategies at the same time (Ahmed et al., 2017; Kassie et al., 2015; Teklewold et al., 2013), is that strategies tend to be subject to high degrees of redundancy, i.e. many strategies were tools to achieve the same (sets of) goals and are therefore substitutable or complementary adoption options.

Paradoxically, the more different options are available to people, the less likely they are to make rational choices because they will give more weight to anecdotal evidence (Schwartz, 2015). There is no reason to believe that this will not apply to farmers. This means that as more strategies become known and available to farmers, it becomes increasingly important to measure not only farmers' household characteristics, but also their perceptions about the benefits of different livelihood strategies. If we do not do the latter, it will become more and more difficult to predict and explain farmers' adoption decisions. Indeed, studies that have explored the relationship between farmers' goals and management decisions have found that the first has a significant effect on the latter (Berkhout et al., 2010; Jambo et al., n.d.). Considering the wealth of adoption studies that have been performed in sub-Saharan Africa (SSA), however, the attention to farmers' goals has been strikingly low (Berkhout et al., 2010) and even the studies that do consider farmers' goals justify their selection of goals on literature reviews of research performed in developed countries (Berkhout et al., 2010; Jambo et al., n.d.). To our knowledge, Okello et al. (2019) is the only other study that has identified the goals of East African smallholder farmers empirically.

The methods presented in this study can be applied to other regions in Ethiopia or other countries in SSA to gain a better understanding of the different types of goals that drive smallholder farmers' management decisions. This knowledge can be used to inform policy makers and industry or researchers developing agronomic innovations for smallholder farmers about which policies might be most effective and which benefits innovations need to have in order to be adopted. Both the development of policies and innovations with higher adoption rates is essential to ensure Ethiopia and other countries in SSA will maintain (or reach) a status of food self-sufficiency (van Ittersum et al., 2016). Future studies should, however, enable farmers' to express a wider range of opinions in step 2. Additionally, the two-step approach would benefit from brain storming sessions with farmers and other stakeholders prior to step 2. With such a brainstorming session, the likelihood of identifying superior strategies may be improved (Abate et al., 2011). In CRV and Jimma such brainstorming sessions could still be held. Furthermore, econometric research in these regions or other regions with similar socio-ecological niches (Ojiem et al., 2006) could be performed to get knowledge about the importance of the various goals (identified in this study) on farmers' management decisions.

5 Conclusions

This study identified the livelihood improvement strategies farmers wanted to implement and which factors constrained or enabled their implementation of these. Based on the goals and constraints farmers faced, it assessed whether researchers' innovations, three applications of inorganic fertilizer, higher rates of inorganic fertilizer and an increased planting density, were likely to be adopted. The results revealed that three applications of inorganic fertilizer was unlikely to be adopted since it was not perceived to perform better than two applications of inorganic fertilizer. It was also considered unlikely that application of higher rates of inorganic fertilizer would be adopted in CRV since the innovation was perceived to be poorly aligned with farmers' goals. To increase the likelihood that farmers will adopt an improved fertilizer management in CRV, it would be beneficial to look at other aspects of farmers' management that could be improved as well, such as for instance their rain water management. In Jimma, farmers' perceived the potential of increased rates of inorganic fertilizer to contribute to their goals to be quite high. Farmers were, however, constrained by their lack of financial capital, labour and access to good quality inorganic fertilizer. These constraints cannot be addressed through agronomic innovation alone. Therefore measures at community or regional levels should be implemented to enable more farmers to adopt improved fertilizer management. Farmers' adoption of increased planting densities was found to be unlikely in the short term, since farmers were uncertain about the actual benefit that they could expect. Farmers did, however, tell us that they would perform their own planting density experiments and considered the potential of the innovation to be highly compatible with their goals. In the medium to long term the experimentation is likely to reveal the benefits of increased planting density to farmers in Jimma but not in CRV since responses there were low.

This study also identified farmers' most important goals: improving the standard of living and food security of their households. Combined implementation of maize strategies (e.g. narrow planting density) and cropland or farm-level strategies (e.g. cash crop diversification) was put forward as the most promising approach to achieve these goals, but requires that the constraints farmers face at a personal, household and regional level (in Jimma) are addressed. To alleviate farmers' knowledge gaps, the creation of information provision networks for (and by) farmers was advised. To address farmers financial constraints credit, needed for to transition to a new farming system, could be provided through these networks. Labour and land constraints could be mitigated through the facilitation of land sharing and group farming. To enable farmers to implement maize strategies, institutional constraints concerning the quality of seed, inorganic fertilizer and other inputs would have to be addressed in Jimma. Additionally, these inputs would need to be affordable. To this end, we recommended that the Agricultural Input Supply Enterprise, the various seed suppliers, and the cooperative unions should be strengthened and more strictly regulated.

Further, this study showed that farmers' know about and desire to implement a large range of livelihood improvement strategies, and that these strategies tend to be complementary and substitutable. Since farmers choices become more influenced by anecdotal evidence as their range of choices expands, their (non-)adoption might appear to be less predictable in the future. To understand farmers' management decisions it will therefore be crucial that farmers' perceptions, and not only their socio-economic characteristics, are measured. This study presents methods through which such knowledge may be acquired. The presented two-step approach would, however, benefit from input from farmers and other stakeholders prior to step 2. Future research should also enable farmers to express a wider range of opinions and not only ask farmers about their constraints but also the factors that enable them to implement livelihood improvement strategies.

6 References

Abate, T., Shiferaw, B., Gebeyehu, S., Amsalu, B., Negash, K., Assefa, K., Eshete, M., Aliye, S., Hagmann, J., 2011. A systems and partnership approach to agricultural research for development: Lessons from Ethiopia. Outlook Agric. 40, 213–220. https://doi.org/10.5367/oa.2011.0048

Abate, T., Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., Kassie, M., Bogale, G., Tadesse, B., Keno, T., 2015. Factors that transformed maize productivity in Ethiopia. Food Secur. 7, 965–981. https://doi.org/10.1007/s12571-015-0488-z

Abera, T., Feyisa, D., Friesen, D., 2011. Effects of Crop Rotation and N-P Fertilizer Rate on Grain Yield and Related Characteristics of Maize and Soil Fertility at Bako, Western Oromia, Ethiopia. East African J. Sci. 3, 70–79. https://doi.org/10.4314/eajsci.v3i1.42789

Ahmed, M.H., Geleta, K.M., Tazeze, A., Mesfin, H.M., Tilahun, E.A., 2017. Cropping systems diversification, improved seed, manure and inorganic fertilizer adoption by maize producers of eastern Ethiopia. J. Econ. Struct. 6. https://doi.org/10.1186/s40008-017-0093-8

Albaum, G., 2018. The Likert Scale Revisited. Mark. Res. Soc. Journal. 39, 1–21. https://doi.org/10.1177/147078539703900202

Alem, Y., Broussard, N.H., 2018. The impact of safety nets on technology adoption: a difference-in-differences analysis. Agric. Econ. 49, 13–24. https://doi.org/10.1111/agec.12392

Amare, A., Simane, B., 2017. Determinants of smallholder farmers' decision to adopt adaptation options to climate change and variability in the Muger Sub basin of the Upper Blue Nile basin of Ethiopia. Agric. Food Secur. 6, 1–20. https://doi.org/10.1186/s40066-017-0144-2

Andersen, D.L., Luna-Reyes, L.F., Diker, V.G., Black, L., Rich, E., Andersen, D.F., 2012. The disconfirmatory interview as a strategy for the assessment of system dynamics models. Syst. Dyn. Rev. 28, 255–275.

Asrat, P., Simane, B., 2017. Household- and plot-level impacts of sustainable land management practices in the face of climate variability and change: Empirical evidence from Dabus Sub-basin, Blue Nile River, Ethiopia. Agric. Food Secur. 6, 1–12. https://doi.org/10.1186/s40066-017-0148-y

Assefa, A., Assefa, B., Descheemaeker, K., van Dijk, M., Getaneh, F., Jongeneel, R., Kenea, W., van Loon, M., Morley, T., Reidsma, P., Silva, J.V., Tesfaye, K., van Ittersum, M., 2017. Reducing The Maize Yield Gap In Ethiopia: Analysis And Policy Simulation. Ethiop. Econ. Assoc. 2–5.

Barrett, C.B., 2008. Smallholder market participation: Concepts and evidence from eastern and southern Africa. Food Policy 33, 299–317. https://doi.org/10.1016/j.foodpol.2007.10.005

Bellon, M.R., 2001. Participatory Research Methods for Technology Evaluation: A Manual for Scientists Working with Farmers. International Maize and Wheat Improvement Center (CIMMYT), Mexico.

Berkhout, E.D., Schipper, R.A., Kuyvenhoven, A., Coulibaly, O., 2010. Does heterogeneity in goals and preferences affect efficiency? A case study of farm households in northern Nigeria. Agric. Econ. 41, 265–273. https://doi.org/10.1111/j.1574-0862.2010.00449.x

Beshir, H., Emana, B., Kassa, B., Haji, J., 2012. Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia: the double hurdle approach. J. Res. Econ. Int. Financ. 1, 39–49.

Bi, C., 2009. Research and application of SQLite embedded database technology. WSEAS Trans. Comput. 8, 83–92.

Chandra, Y., Shang, L., 2017. An RQDA-based constructivist methodology for qualitative research. Qual. Mark. Res. 20, 90–112. https://doi.org/10.1108/QMR-02-2016-0014

de Groote, H., Gunaratna, N.S., Fisher, M., Kebebe, E.G., Mmbando, F., Friesen, D., 2016. The effectiveness of extension strategies for increasing the adoption of biofortified crops: the case of quality protein maize in East Africa. Food Secur. 8, 1101–1121. https://doi.org/10.1007/s12571-016-0621-7

Deci, E.L., Ryan, R.M., 2008. Self-determination theory: A macrotheory of human motivation, development, and health. Can. Psychol. 49, 182–185. https://doi.org/10.1037/a0012801

Dercon, S., Gilligan, D.O., Hoddinott, J., Woldehanna, T., 2009. The impact of agricultural extension and roads on poverty and consumption growth in fifteen Ethiopian Villages. Am. J. Agric. Econ. 91, 1007–1021. https://doi.org/10.1111/j.1467-8276.2009.01325.x

Descheemaeker, K., Ronner, E., Ollenburger, M., Franke, A.C., Klapwijk, C.J., Falconnier, G.N., Wichern, J., Giller, K.E., 2016. Which Options Fit Best? Operationalizing the Socio-Ecological Niche Concept. Exp. Agric. 1–22. https://doi.org/10.1017/S001447971600048X

Dorfman, J.H., 1996. Modeling Multiple Adoption Decisions in a Joint Framework. Am. J. Agric. Econ. 78, 547–557. https://doi.org/10.2307/1243273

Duguma, B., Dermauw, V., Janssens, G., 2017. The assessment and the farmers' perceived ranking of feed resources and coping strategies with feed scarcity in smallholder dairy farming in selected district towns of Jimma Zone, Ethiopia. Trop. Anim. Health Prod. 49, 923–935. https://doi.org/10.1007/s11250-017-1274-z

FAO, 2007. The State of the World's Animal Genetic Resources for Food and Agriculture, FAO. FAO, Rome.

Fufa, B., Hassan, R.M., 2006. Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption. Agrekon 45, 38–49. https://doi.org/10.1080/03031853.2006.9523732

Gabriel, A.H., Hundie, B., 2006. Farmers' Post-Harvest Grain Management Choices under Liquidity Constraints and Impending Risks: Implications for Achieving Food Security Objectives in Ethiopia, in: International Association of Agricultural Economists, Ausgust 12-18, 2006. Gold Goast, Australia, pp. 1–17.

Getnet, K., MacAlister, C., 2012. Integrated innovations and recommendation domains: Paradigm for developing, scaling-out, and targeting rainwater management innovations. Ecol. Econ. 76, 34–41. https://doi.org/10.1016/j.ecolecon.2012.02.003

Getnet, M., Van Ittersum, M., Hengsdijk, H., Descheemaeker, K., 2016. Yield gaps and resource use across farming zones in the central rift valley of Ethiopia. Exp. Agric. 52, 493–517. https://doi.org/10.1017/S0014479715000216

Gioia, D.A., Corley, K.G., Hamilton, A.L., 2012. Seeking Qualitative Rigor in Inductive Research. Organ. Res.

Methods 16, 15–31. https://doi.org/10.1177/1094428112452151

Gorban, A.N., Pokidysheva, L.I., Smirnova, E. V., Tyukina, T.A., 2011. Law of the Minimum Paradoxes. Bull. Math. Biol. https://doi.org/10.1007/s11538-010-9597-1

Gutman, J., 1997. Means End Chains and Laddering. Psychol. Mark. 14, 545–560.

Helmes, E., Holden, R.R., Ziegler, M., 2015. Response Bias, Malingering, and Impression Management. Meas. Personal. Soc. Psychol. Constr. 16–43. https://doi.org/10.1016/B978-0-12-386915-9.00002-4

Hochberg, Y., Benjamini, Y., 1995. Controlling the False Discovery Rate: a Practical and Powerful Approach to Multiple Testing. J. R. Stat. Soc. https://doi.org/10.1017/CBO9781107415324.004

House, E.R., 2007. Realism in Research. Educ. Res. https://doi.org/10.3102/0013189x020006002

Huang, R., 2018. RQDA: R-based Qualitative Data Analysis.

Jaleta, M., Kassie, M., Marenya, P., Yirga, C., Ernstein, O., 2015. Impact of Improved Maize Variety Adoption on Household Food Security in Ethiopia: An Endogenous Switching Regression Approach. Int. Conf. Agric. Econ. 1–26.

Jambo, I.J., Groot, J., Descheemaeker, K., Bekunda, M., Tittonell, P., n.d. Motivations for the use of sustainable intensification practices among smallholder farmers in Tanzania and Malawi. NJAS.

Kassie, B.T., Van Ittersum, M.K., Hengsdijk, H., Asseng, S., Wolf, J., Rötter, R.P., 2014. Climate-induced yield variability and yield gaps of maize (Zea mays L.) in the Central Rift Valley of Ethiopia. F. Crop. Res. 160, 41–53. https://doi.org/10.1016/j.fcr.2014.02.010

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P., Erenstein, O., 2015. Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. Land use policy 42, 400–411. https://doi.org/10.1016/j.landusepol.2014.08.016

Kenea, W., n.d. To develop and adapt optimal farm plans and assess how they can mitigate maize yield gaps in Ethiopia. undetermined.

Ketema, M., Bauer, S., 2011. Determinants of manure and fertilizer applications in eastern highlands of Ethiopia. Q. J. Int. Agric. 50, 237–252.

Knutsson, P., 2006. The sustainable livelihoods approach: A framework for knowledge integration assessment. Hum. Ecol. Rev.

Likert, R., 1932. A Technique For The Measurement of Attitudes. Arch. Psychol. 22, 5–55. https://doi.org/2731047

Mann, H.B., Whitney, D.R., 1947. On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other. Ann. Math. Stat. https://doi.org/10.1214/aoms/1177730491

Marra, M., Pannell, D.J., Abadi Ghadim, A., 2003. The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? Agric. Syst. 75, 215–234. https://doi.org/10.1016/S0308-521X(02)00066-5

Mashingaidze, N., Twomlow, S., Madakadze, I.C., Mupangwa, W., Mavunganidze, Z., 2017. Weed growth and crop yield responses to tillage and mulching under different crop rotation sequences in semi-arid conditions.

Soil Use Manag. 33, 311–327. https://doi.org/10.1111/sum.12338

Maslow, A.H., 1943. Theory of Human Motivation. Psycological Rev.

McArthur, J.W., McCord, G.C., 2017. Fertilizing growth: Agricultural inputs and their effects in economic development. J. Dev. Econ. 127, 133–152. https://doi.org/10.1016/j.jdeveco.2017.02.007

Murage, A.W., Midega, C.A.O., Pittchar, J.O., Pickett, J.A., Khan, Z.R., 2015. Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. Food Secur. 7, 709–724. https://doi.org/10.1007/s12571-015-0454-9

Ojiem, J.O., de Ridder, N., Vanlauwe, B., Giller, K.E., 2006. Socio-ecological niche: A conceptual framework for integration of legumes in smallholder farming systems. Int. J. Agric. Sustain. 4, 79–93. https://doi.org/10.1080/14735903.2006.9686011

Okello, J., Zhou, Y., Barker, I., Schulte-Geldermann, E., 2019. Correction to: Motivations and Mental Models Associated with Smallholder Farmers' Adoption of Improved Agricultural Technology: Evidence from Use of Quality Seed Potato in Kenya. Eur. J. Dev. Res. 31, 271–292. https://doi.org/10.1057/s41287-018-0159-y

Pamuk, H., Bulte, E., Adekunle, A.A., 2014. Do decentralized innovation systems promote agricultural technology adoptionα Experimental evidence from Africa. Food Policy 44, 227–236. https://doi.org/10.1016/j.foodpol.2013.09.015

Pannell, D.J., Marshall, G.R., Barr, N., Vanclay, F., Wilkinson, R., Curtis, A., 2006. Understanding and promoting adoption of conservation practices by rural landholders. Aust. J. Exp. Agric. 46, 1407. https://doi.org/10.1071/ea05037

R core team, 2018. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.

Rashid, S., Getnet, K., Lemma, S., 2010. Maize Value Chain Potential in Ethiopia: Constraints and Opportunities for Enhancing the System. Washington, DC.

Robson, C., McCartan, K., 2016. Real World Research: A Resource for Social Scientists and Pratitioner-Researchers., 4th ed, Doing Research in the Real World. Blackwell publishing, Oxford. https://doi.org/10.1192/pb.30.2.43

Rogers, E.M., 2003. Diffusion of innovations, 16th ed. Free Press, New York.

Ronner, E., Descheemaeker, K., Marinus, W., Almekinders, C.J.M., Ebanyat, P., Giller, K.E., 2018. How do climbing beans fit in farming systems of the eastern highlands of Uganda? Understanding opportunities and constraints at farm level. Agric. Syst. 165, 97–110. https://doi.org/10.1016/j.agsy.2018.05.014

Ruben, R., Kruseman, G., Kuyvenhoven, A., 2006. Strategies for sustainable intensification in East African highlands: Labor use and input efficiency, in: Agricultural Economics. https://doi.org/10.1111/j.1574-0864.2006.00116.x

Schut, M., van Asten, P., Okafor, C., Hicintuka, C., Mapatano, S., Nabahungu, N.L., Kagabo, D., Muchunguzi, P., Njukwe, E., Dontsop-Nguezet, P.M., Sartas, M., Vanlauwe, B., 2016. Sustainable intensification of agricultural systems in the Central African Highlands: The need for institutional innovation. Agric. Syst. 145, 165–176. https://doi.org/10.1016/j.agsy.2016.03.005

Schwartz, B., 2015. The Paradox of Choice, in: Positive Psychology in Practice: Promoting Human Flourishing in Work, Health, Education, and Everyday Life: Second Edition. https://doi.org/10.1002/9781118996874.ch8

Scoones, I., Thompson, J., 2009. Farmer first revisited: Innovation for agricultural research and development. Practical Action Publishing Ltd, Warwickshire.

Silva, J.V., Getaneh, F., Tesfaye, K., 2016. Methodology underlying the household survey conducted in Bako Tibe (Western Oromia) and Adami Tulu (Central Rift Valley), Ethiopia.

Spielman, D.J., Kelemwork, D., Alemu, D., 2011. Seed, Fertilizer, and Agricultural Extension in Ethiopia. Dev. Strateg. Gov. Div. Int. Food Policy Res. Inst. – Ethiop. Strateg. Support Progr. II, Ethiop. 1–41. https://doi.org/10.9783/9780812208610.84

Sumberg, J., 2006. Constraints to the Adoption of Agricultural Innovations Is it Time to Re-think. Outlook Agric. 34, 7–10. https://doi.org/10.2500/108854191778879368

Tadesse, M., 2014. Fertilizer adoption, credit access, and safety nets in rural Ethiopia. Agric. Financ. Rev. 74, 290–310. https://doi.org/10.1108/AFR-09-2012-0049

TAMASA, 2016. Report of TAMASA Ethiopia activities (2015-2016).

Teklewold, H., Kassie, M., Shiferaw, B., 2013. Adoption of multiple sustainable agricultural practices in rural Ethiopia. J. Agric. Econ. 64, 597–623. https://doi.org/10.1111/1477-9552.12011

United Nations, 2017. World Population Prospects, the 2017 Revision, Working Pa. ed. United Nations, New York.

van Ittersum, M.K., Chikowo, R., Kaizzi, K., Agali, A., Cassman, K.G., van Bussel, L.G.J., van Oort, P.A.J., Wolf, J., Saito, K., Adimo, O., van Wart, J., van Loon, M.P., Makoi, J.H.J.R., Adjei-Nsiah, S., de Groot, H., Grassini, P., Wiebe, K., Guilpart, N., Bala, A., Ouattara, K., Boogaard, H., Tesfaye, K., Yang, H., Kouressy, M., Mason-D'Croz, D., Claessens, L., 2016. Can sub-Saharan Africa feed itself? Proc. Natl. Acad. Sci. 113, 14964–14969. https://doi.org/10.1073/pnas.1610359113

Wickham, H., 2016. ggplot2 - Elegant Graphics for Data Analysis. J. Stat. Softw. https://doi.org/10.18637/jss.v077.b02

Zeng, D., Alwang, J., Norton, G., Jaleta, M., Shiferaw, B., Yirga, C., 2018. Land ownership and technology adoption revisited: Improved maize varieties in Ethiopia. Land use policy 72, 270–279. https://doi.org/10.1016/j.landusepol.2017.12.047

Zeng, D., Alwang, J., Norton, G.W., Shiferaw, B., Jaleta, M., Yirga, C., 2015. Ex post impacts of improved maize varieties on poverty in rural Ethiopia. Agric. Econ. (United Kingdom) 46, 515–526. https://doi.org/10.1111/agec.12178

7 Appendices

7.1 An overview of previous adoption research

Table 8. Research performed on the adoption of farming strategies with potentials to improve the performance of Ethiopian smallholder farms who grow maize. XX in the column of "Other agronomic practices" signifies their consideration two different "other agronomic practices". The search terms: ("perception" or "adoption" or "acceptance") and ("Ethiopia") and ("maize") and ("farming practice" or "agricultural technology") were used. Snowballing was used to find further studies.

	Strategies with potential to improve short-term maize yields...						...long term	Other strategies	
Studies	Inorganic fertilizer	Manure	Improved seed	Irrigation	Push-pull	Other agronomic practices	Sustainable land management	Crop diversification	Livelihood diversification
Ahmed et al., 2017	X	X	X					X	
Alem and Broussard, 2018	X								
Amare and Simane, 2017				X		X			X
Asrat and Simane, 2017							X		
Beshir et al., 2012	X								
Fufa and Hassan, 2006	X								
de Groote et al., 2016			X						
Jaleta et al., 2015			X						
Kassie et al., 2015	X	X	X			X	X	X	
Ketema and Bauer, 2011	X	X							
Getnet and MacAlister, 2012				X			X		
Murage et al., 2015					X				
Tadesse, 2014	X								
Teklewold et al., 2013	X	X	X			XX			
Zeng et al., 2018, 2015			X						

7.2 The scope and objectives of the TAMASA project

Taking Maize Agronomy to Scale in Africa (TAMASA) is a 4-year project (November 2014-October 2018) seeking to improve productivity and profitability for small-scale maize farmers in Ethiopia, Tanzania and Nigeria.

The overall purpose of TAMASA is to use innovative approaches to transform agronomy that:

- Use available geospatial and other data and analytics to map maize areas, soil constraints, and actual and yields at different scale
- Work with service providers (i.e. input suppliers, government and private research and extension services, agro-dealers, and others) to identify and co-develop systems and applications that transform this data and information to useable products that support their businesses or programs to reach clients more effectively
- Build capacity in national programs to support and sustain these approaches

For more information see: http://tamasa.cimmyt.org/

7.3 The background for the two-step approach

The methodology used for data collection built on Bellon (2001) (p. 46 - 66), who proposed a four-phase approach in which farmers' problems ("points of intervention") are identified first, farmers technological options and perceptions thereof are elicited second, different technological options are compared third and constraints are elicited last (Fig. 5). Instead of focus group discussions however, this we collected data from individual farmers to avoid biased results towards more extrovert and higher social status farmers. To facilitate a more intuitive and interviewee-friendly interview build-up, the sequence of the collection of the different types of information was changed (Fig. 5). Through personal interviews, farmers' options for improved livelihood (i.e. strategies) were identified first, the goals driving farmers to want to adopt these strategies were elicited second and the constraints made adoption difficult were elicited third. The semi-quantitative comparison of strategies was performed last in order to be able to include relevant strategies, goals and constraints, as expressed by farmers during interviews.

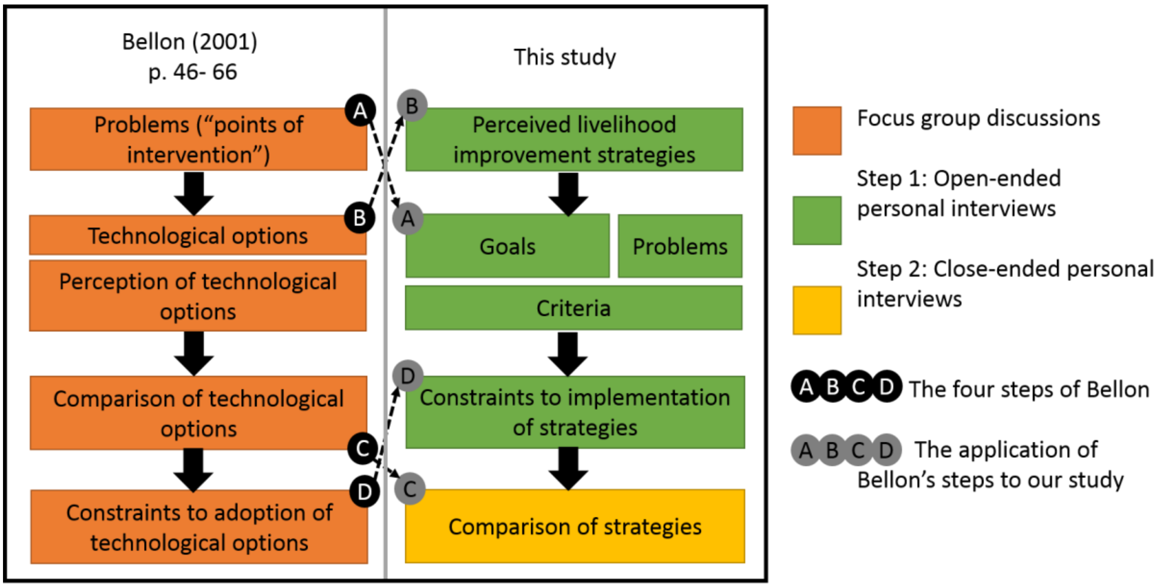


Figure 7. The data collection methods used collect (see different colours) used to explore the different goals, strategies and factors that influence farmers future management decisions. These were used to assess technology suitability and likelihood of adoption

7.4 More in-depth description of disturbance during interviews

When we arrived at a farm our presence was made known to neighbours and friends of the household. We would always make sure no other farmers were listening to the interview, but were not in a position to keep children away. Sometimes, a group of 5-10 children would sit around us throughout the interview. The wife of the farmer would also often be present. Next to children, a lot of farmers were frequently distracted by their livestock, which often walked loose in the yard among piles of harvested maize. In other cases, disturbance was also caused by sudden heavy rain, or by heavy traffic on nearby roads.

Some farmers in Jimma were high on chat, a narcotic drug causing alertness and incoherence, during the interviews. This made them ramble on about themes that were not related to the questions we asked.

7.5 A visual representation of the coding process

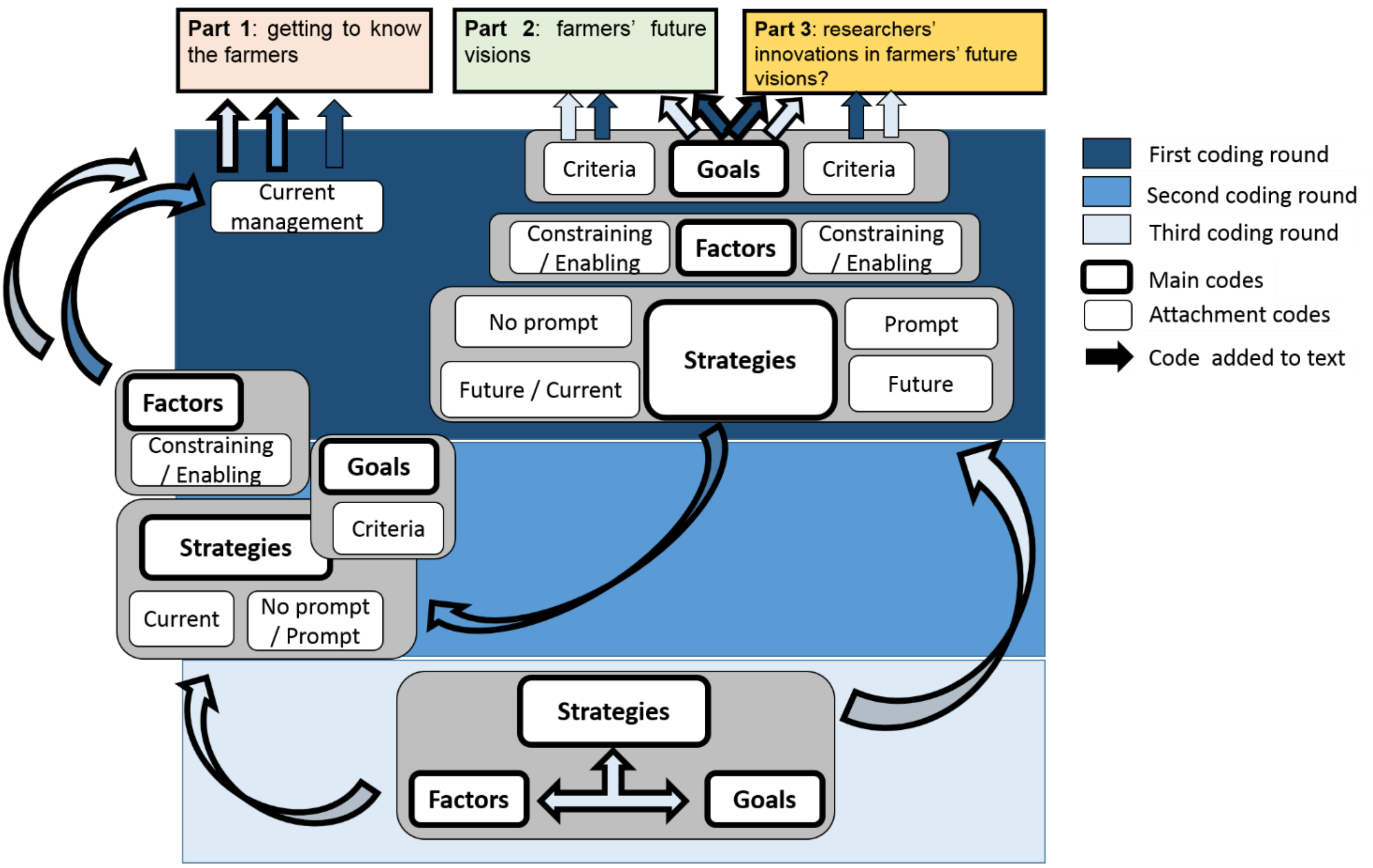
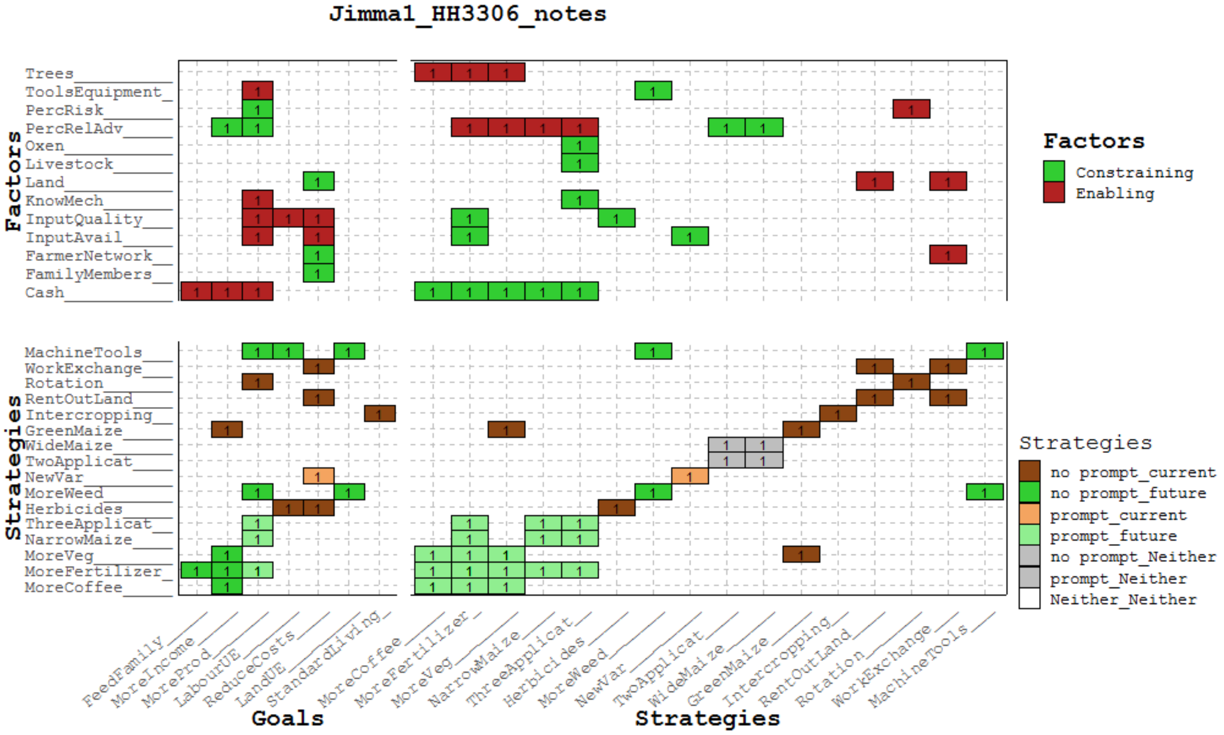
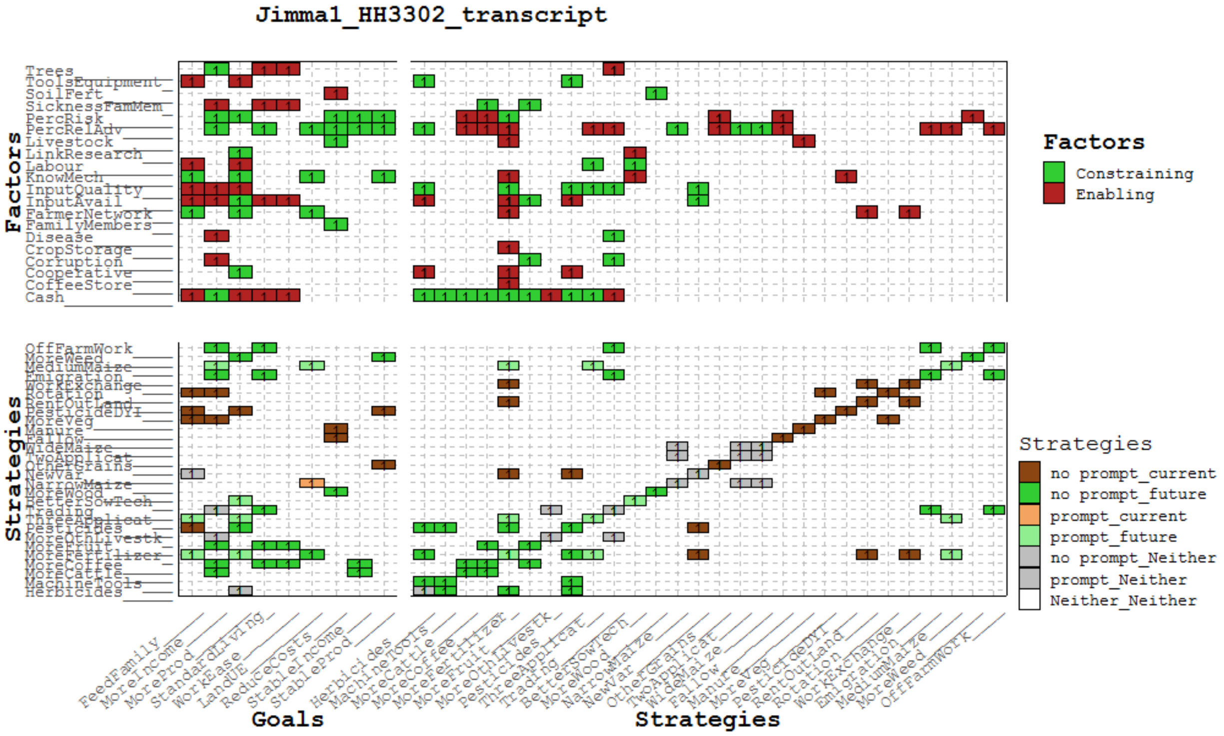


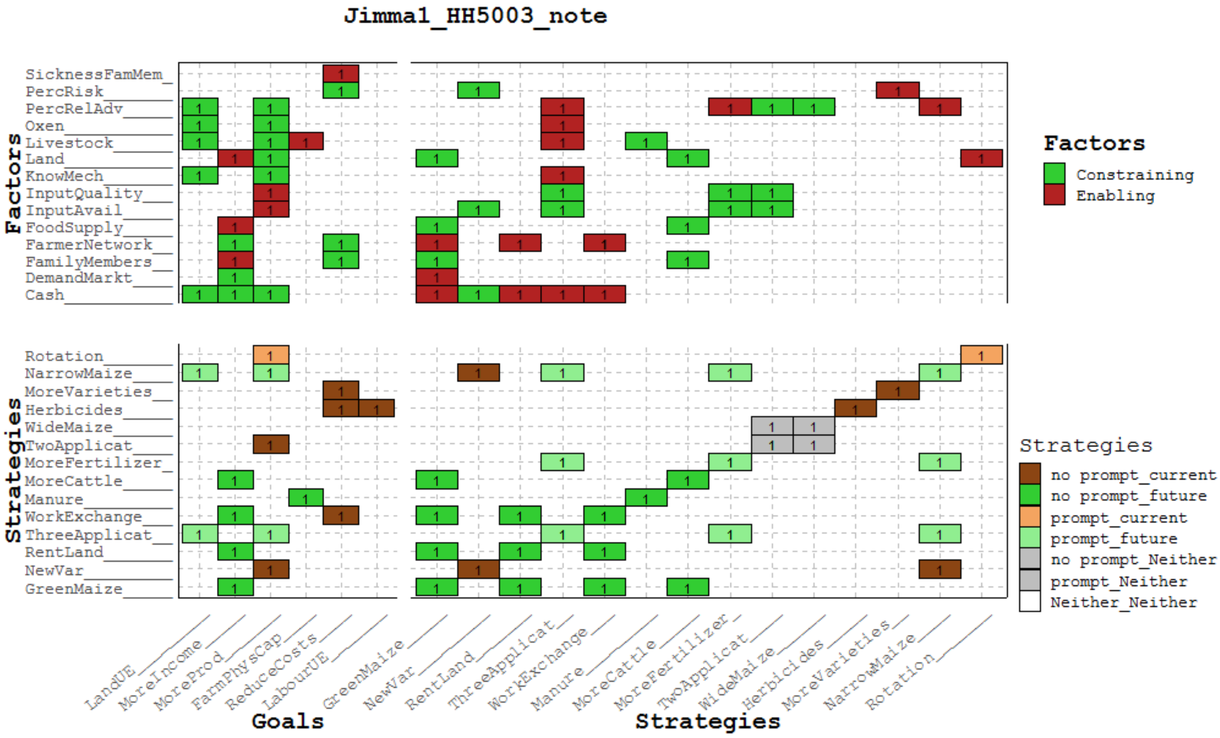
Figure 8. Systematic diagram showing how interviews were coded: In the first round, goal, factor and strategy codes were added to part 2 and 3 of the interviews. Moreover, codes carrying additional information about these codes were attached. Furthermore, part 1 of the interviews were coded with current management codes. In the second coding round, current management practices were reconsidered. If these practices had been coded as strategies by other farmers, they were recoded as strategies with the attachment code "current". If goals for or factors enabling them or making it difficult for them to maintain this management were mentioned, these were also coded. In the third round, the accuracy of the coding of goal, strategy and factors was checked visually using code co-occurrence matrices. By checking the coding a third time, ensuring that for each farmer, causally related strategies, factors and goals co-occurred at least once, the accuracy was improved.

7.6 Co-occurrences of factor codes, strategy codes and goal codes in each individual interview

The R-script used to make these matrices is provided as supplementary material.



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FoodSupply
FarmerNetwork
FamilyMembers
DemandMarkt
Cash
Strategies
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Herbicides
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Manure
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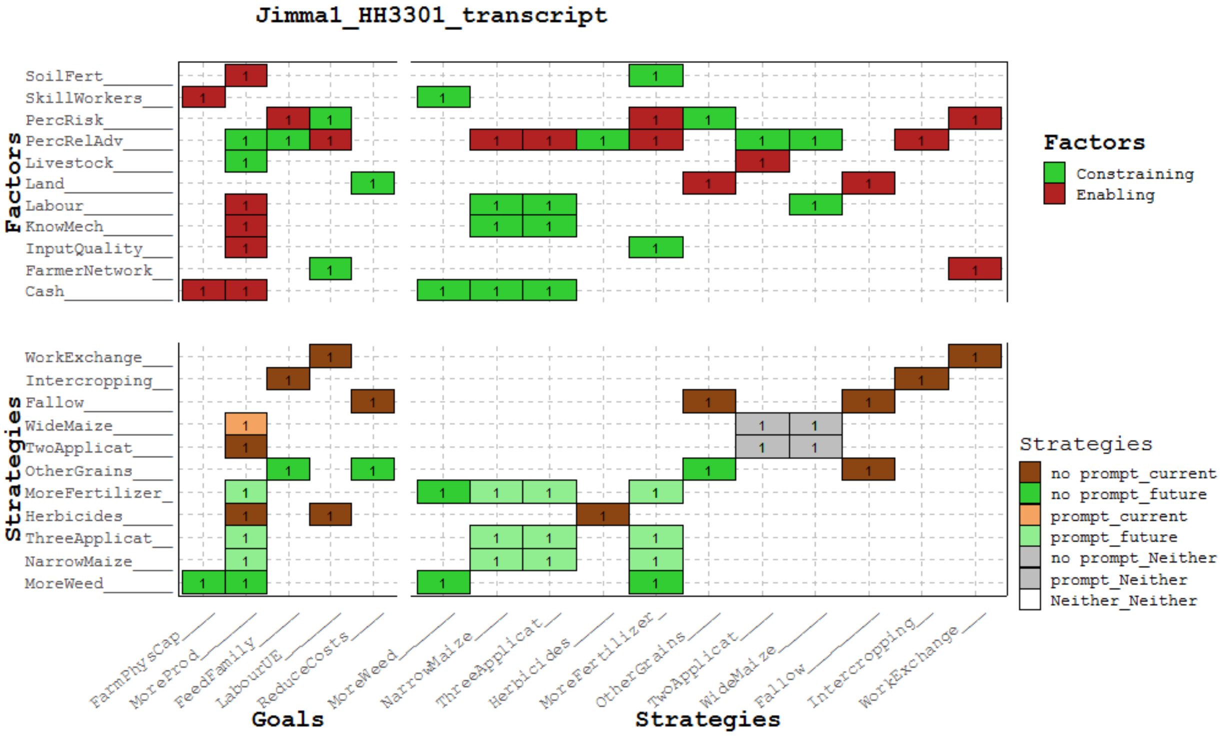
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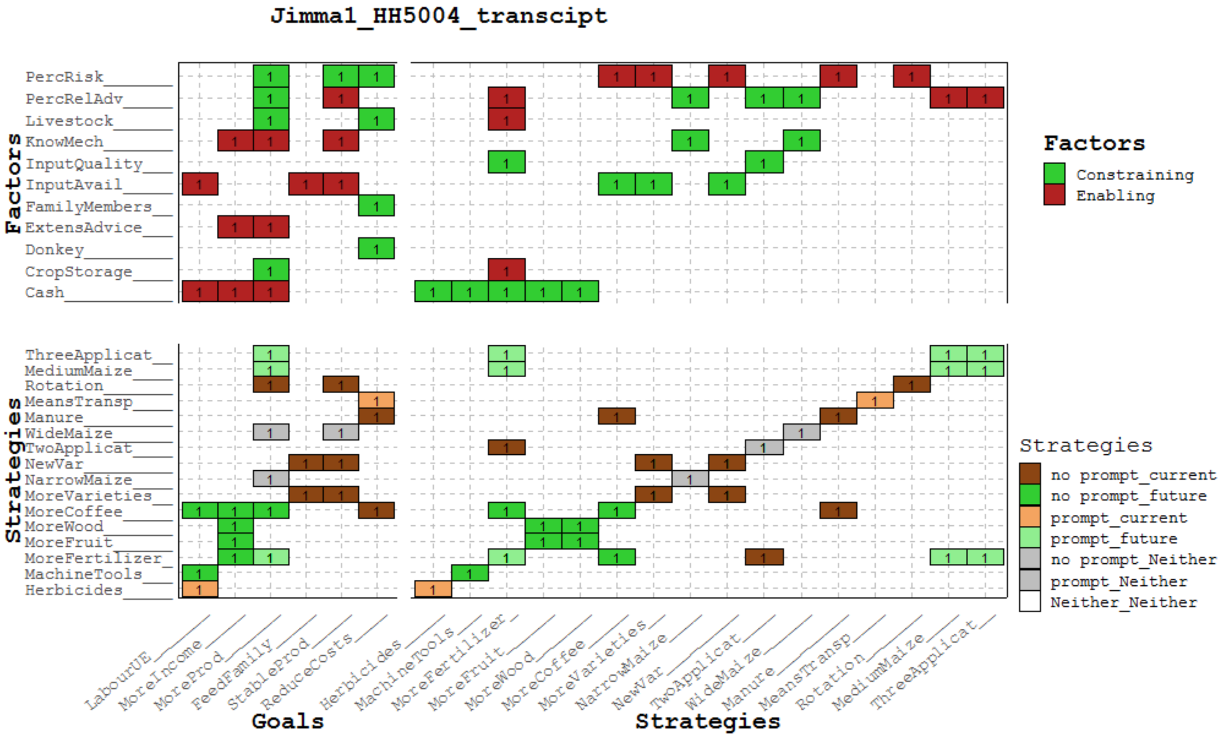
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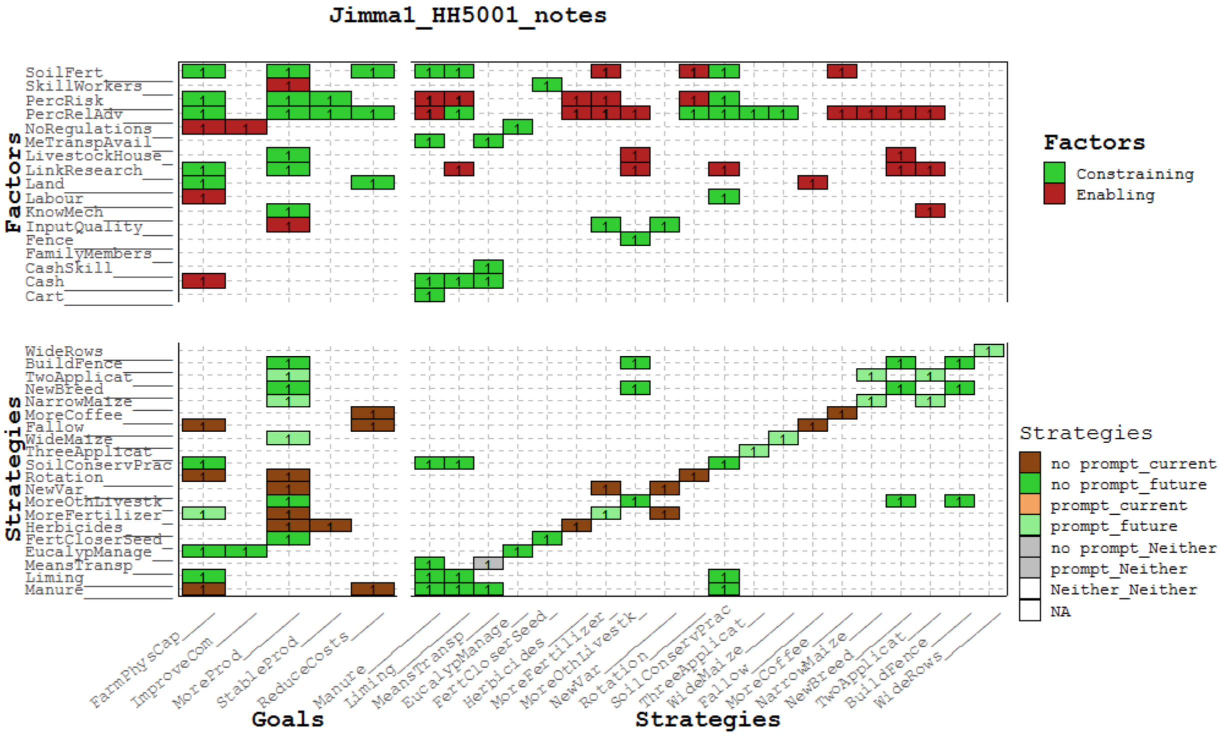
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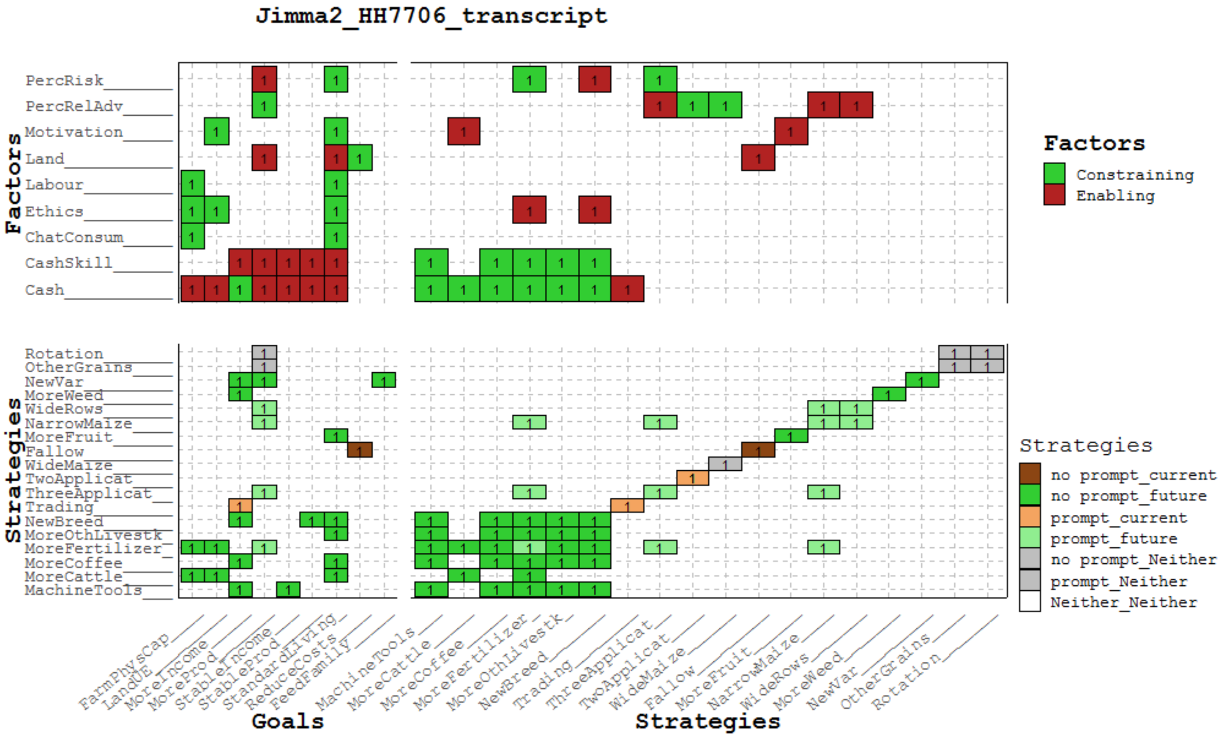
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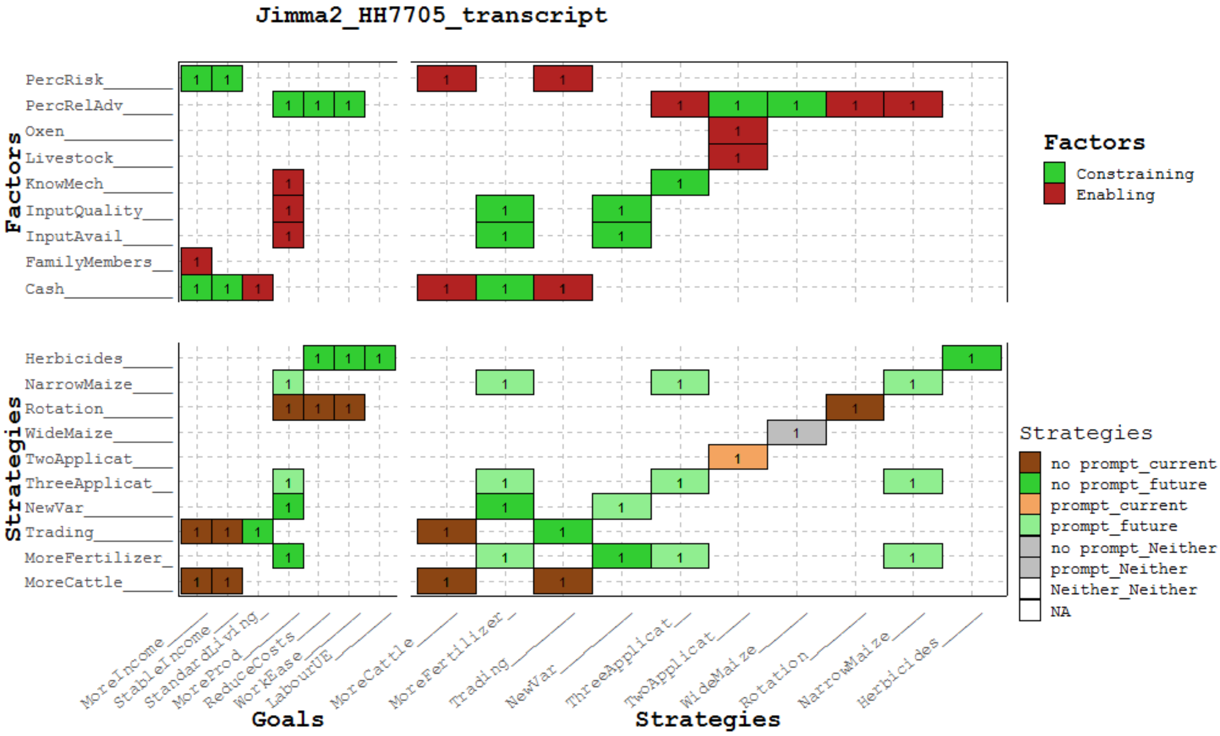
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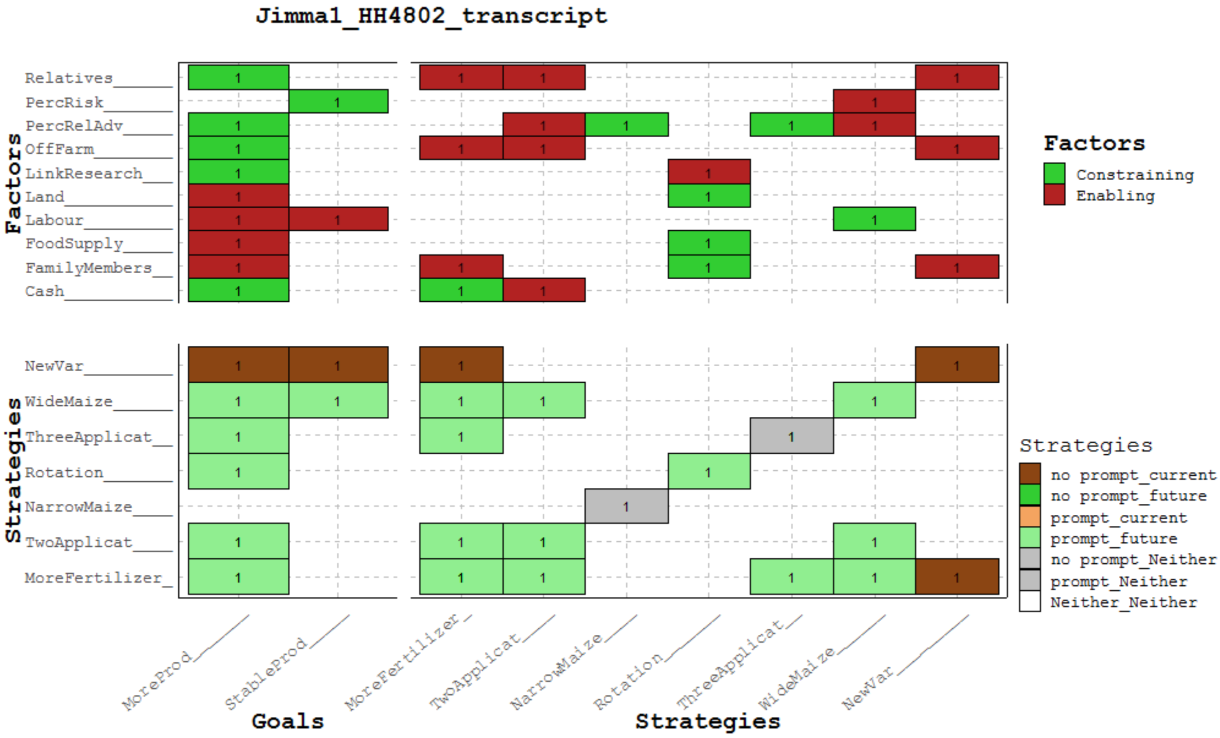
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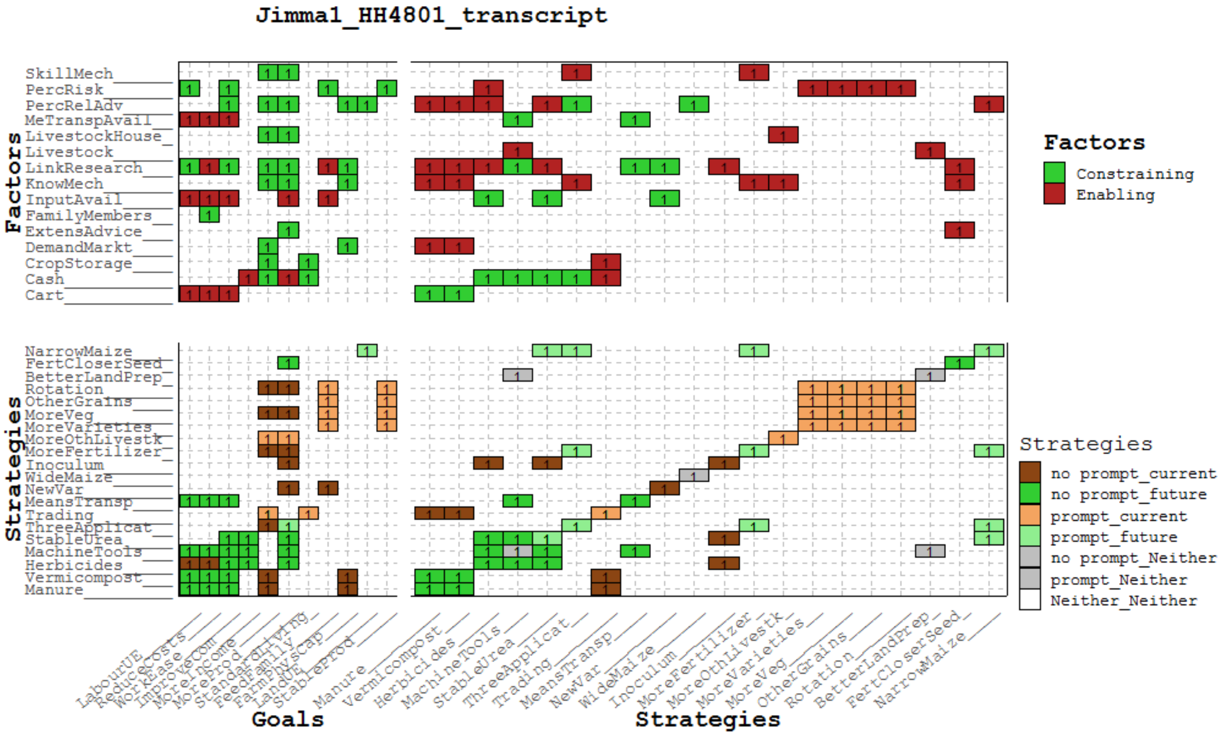
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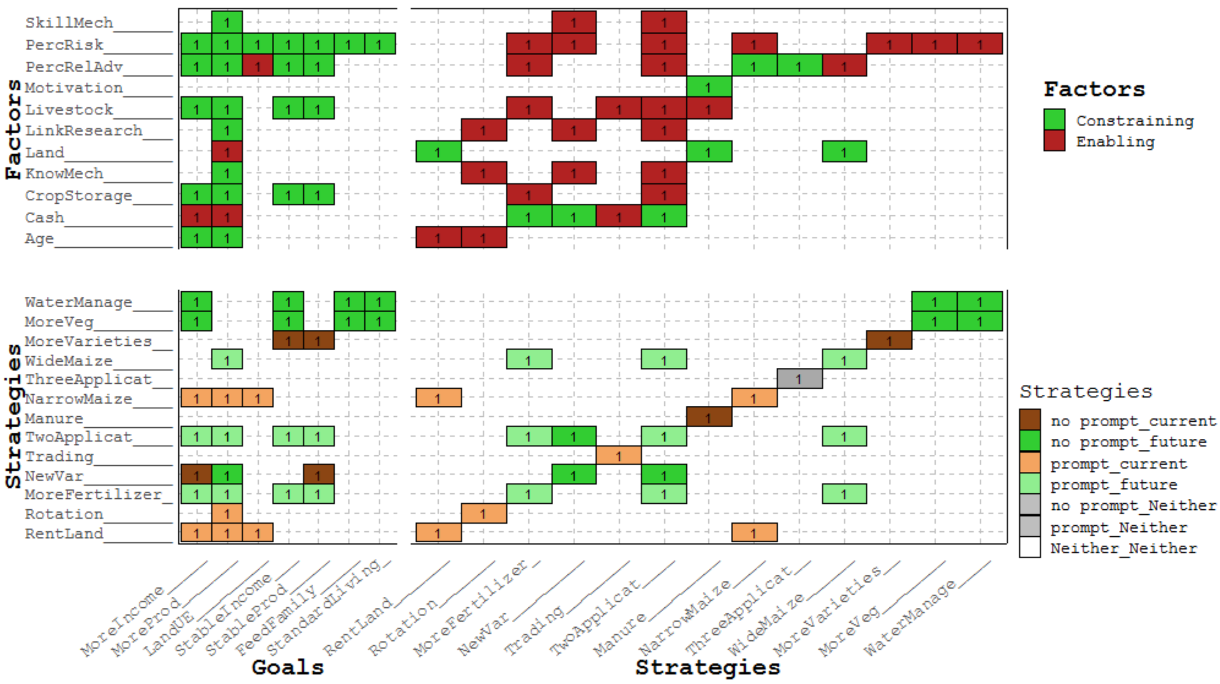

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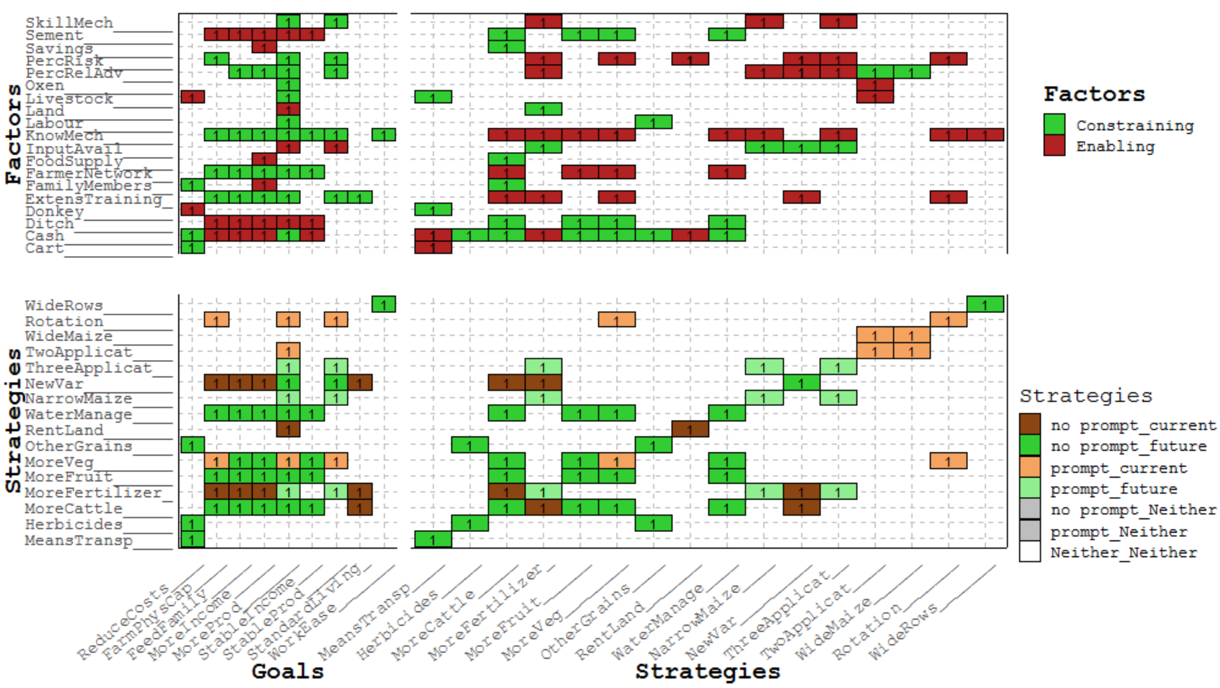

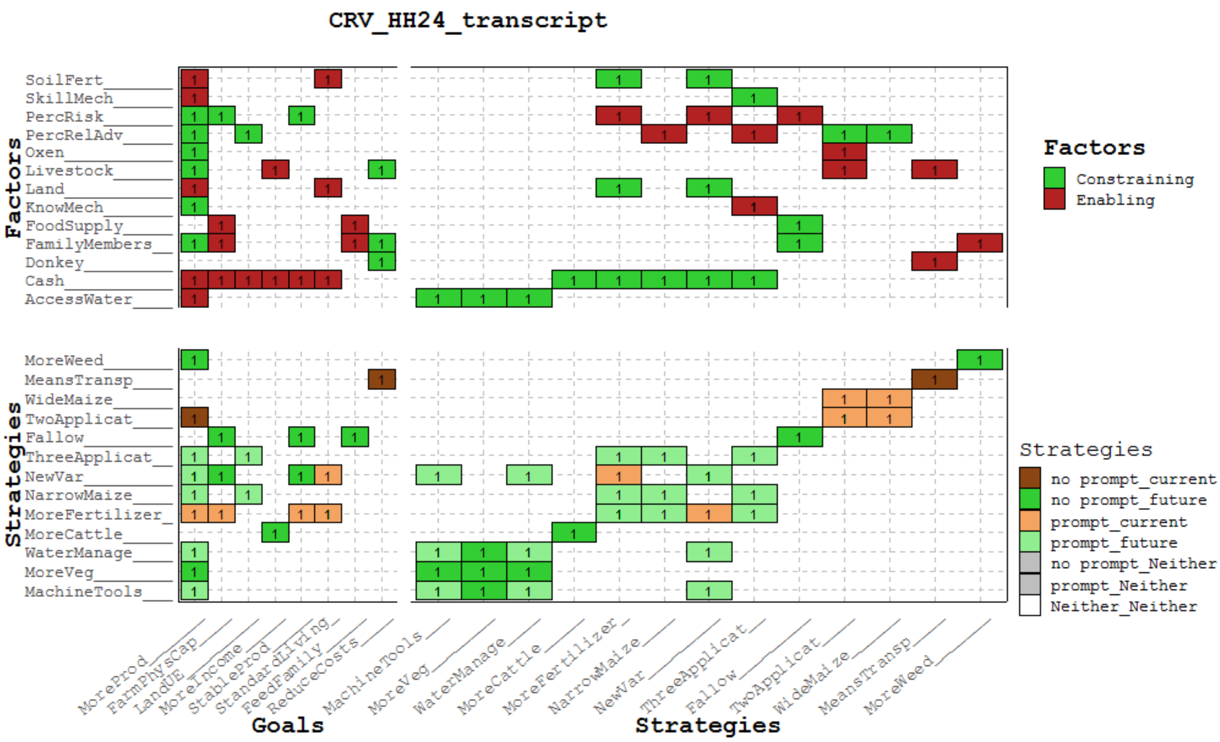
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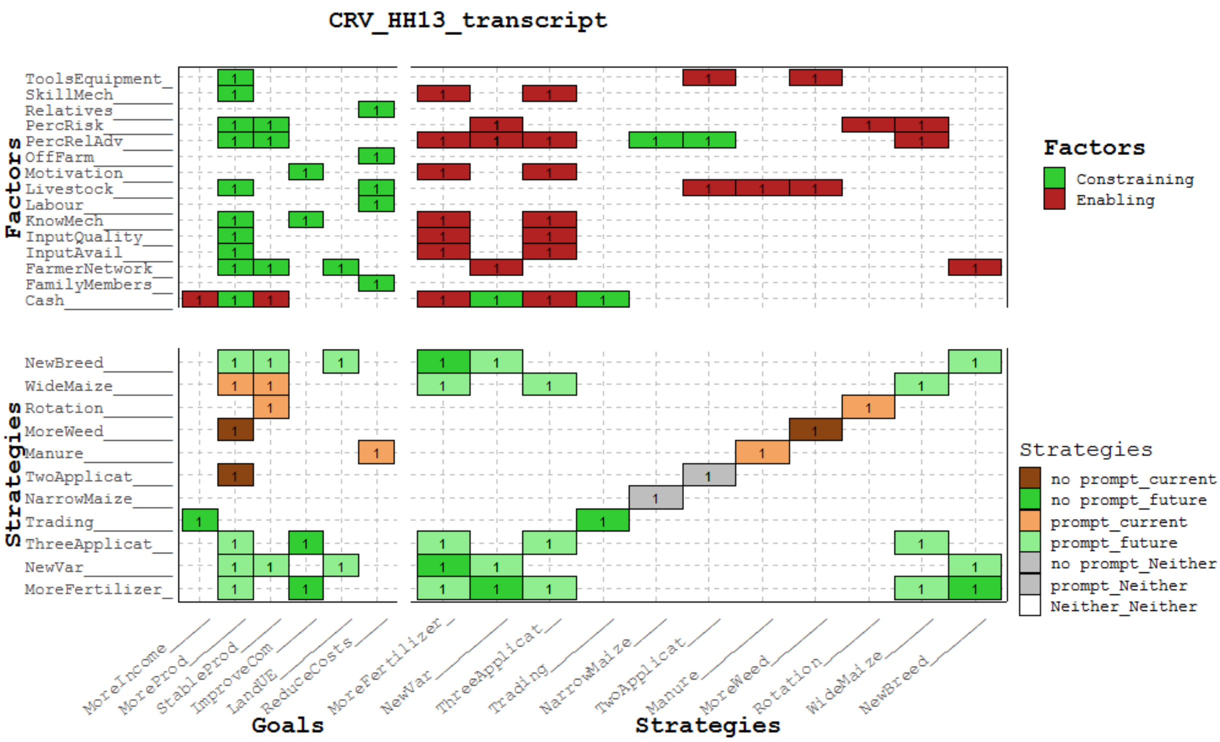
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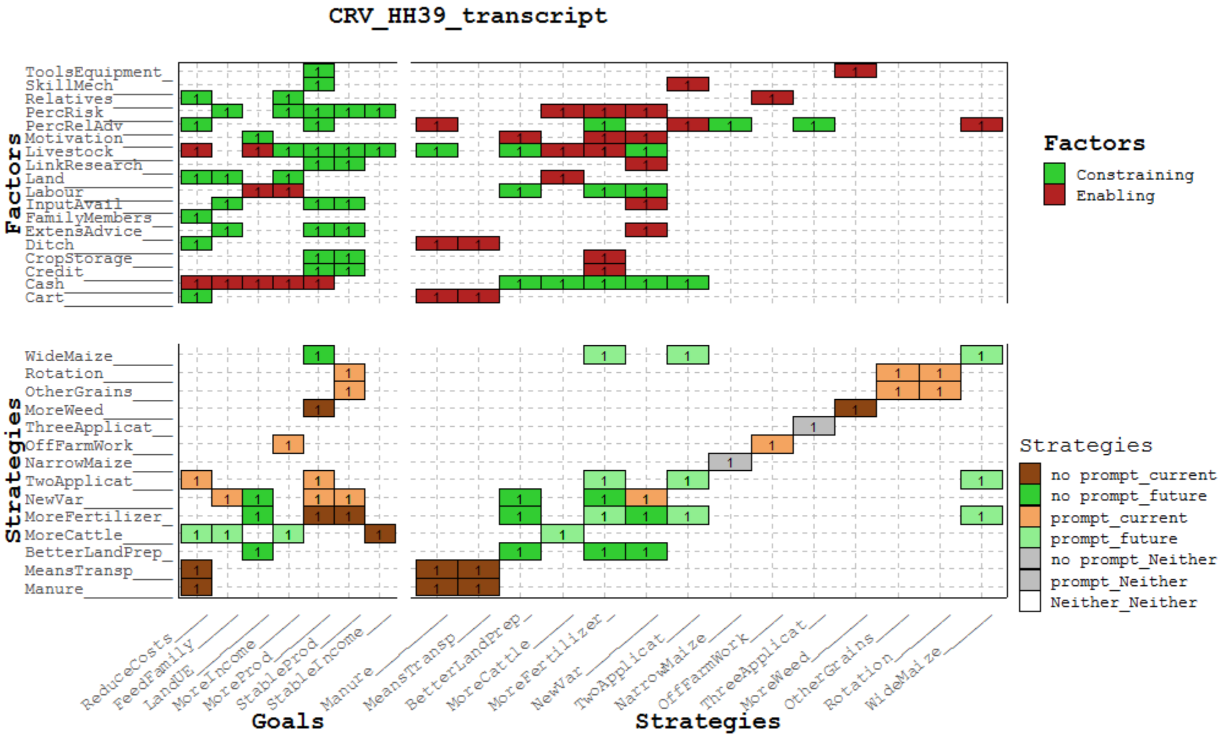
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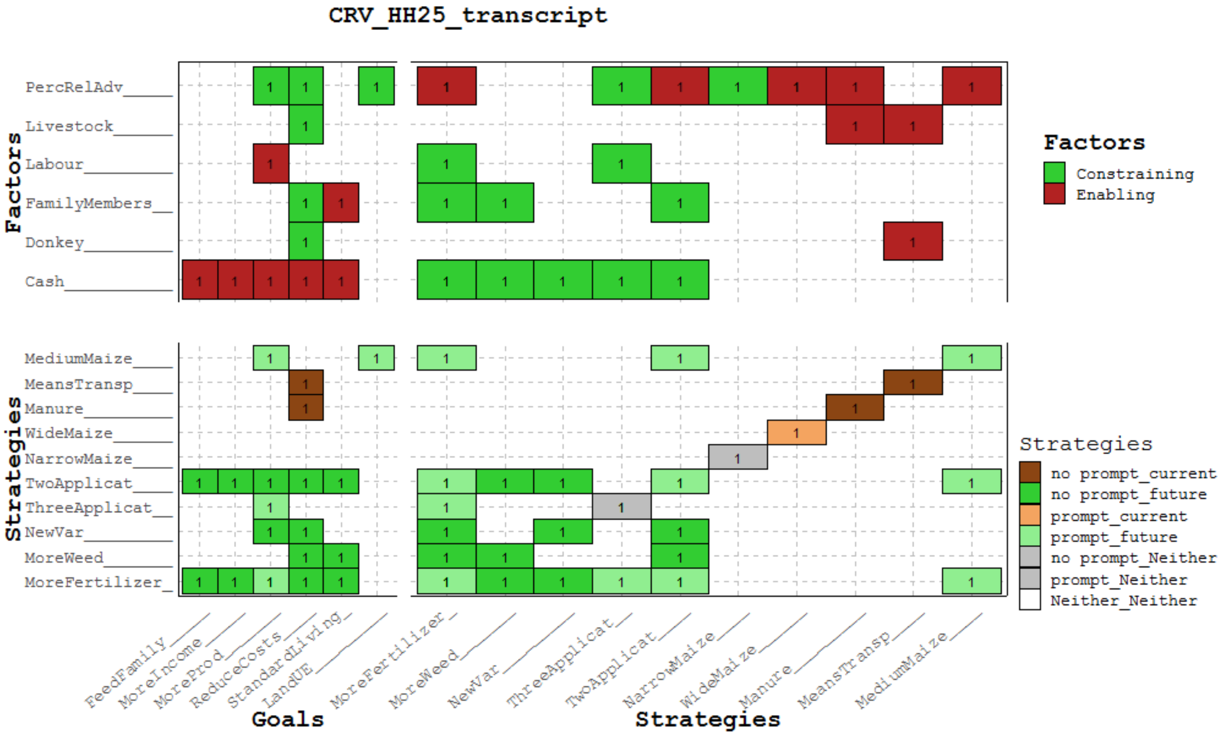
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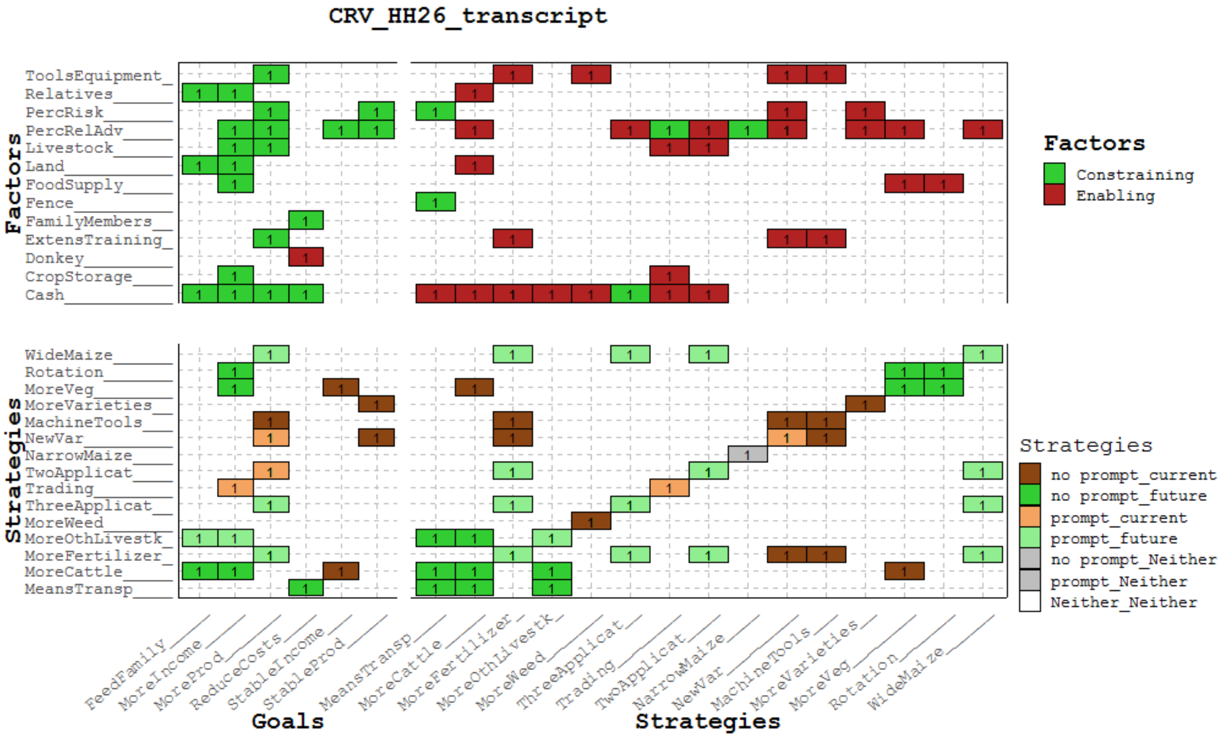

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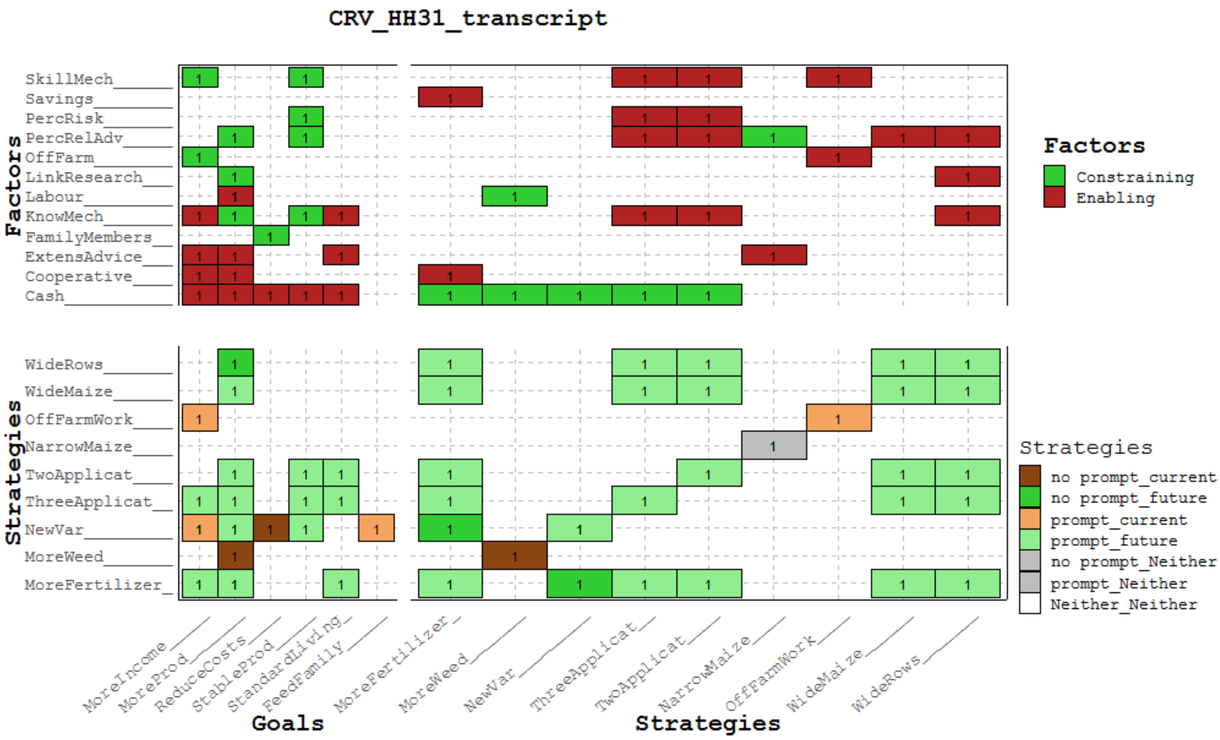

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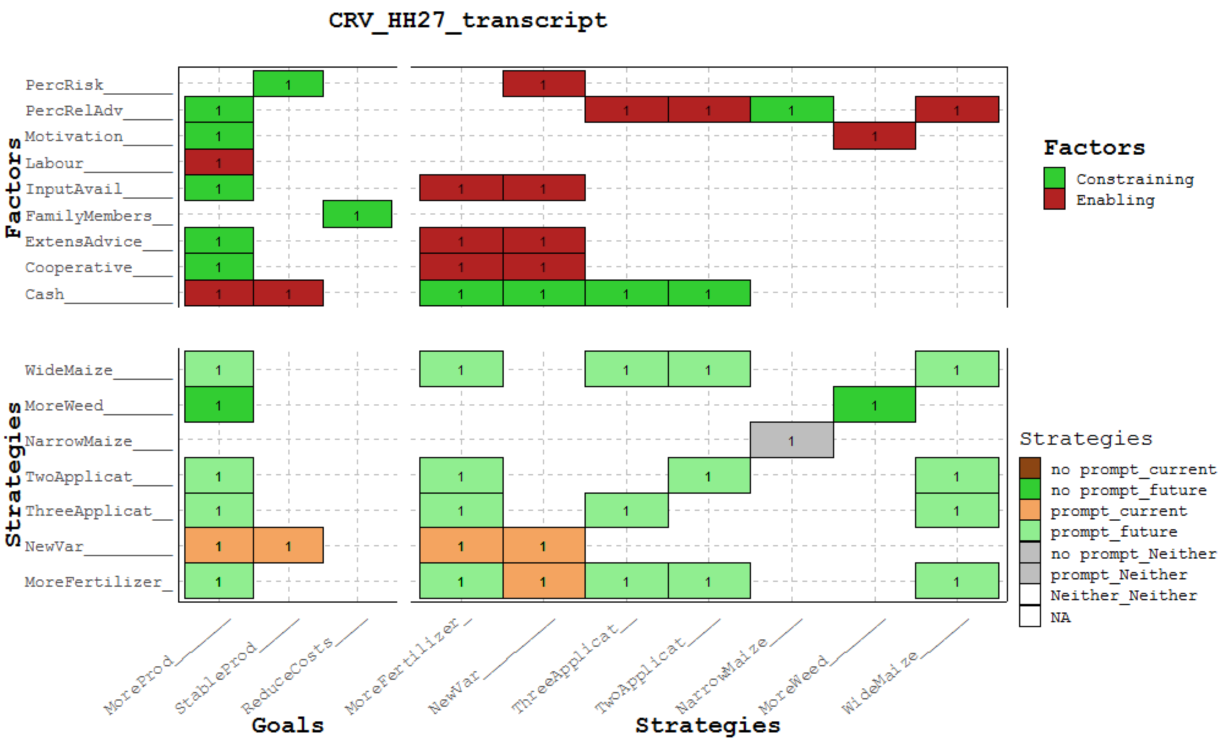

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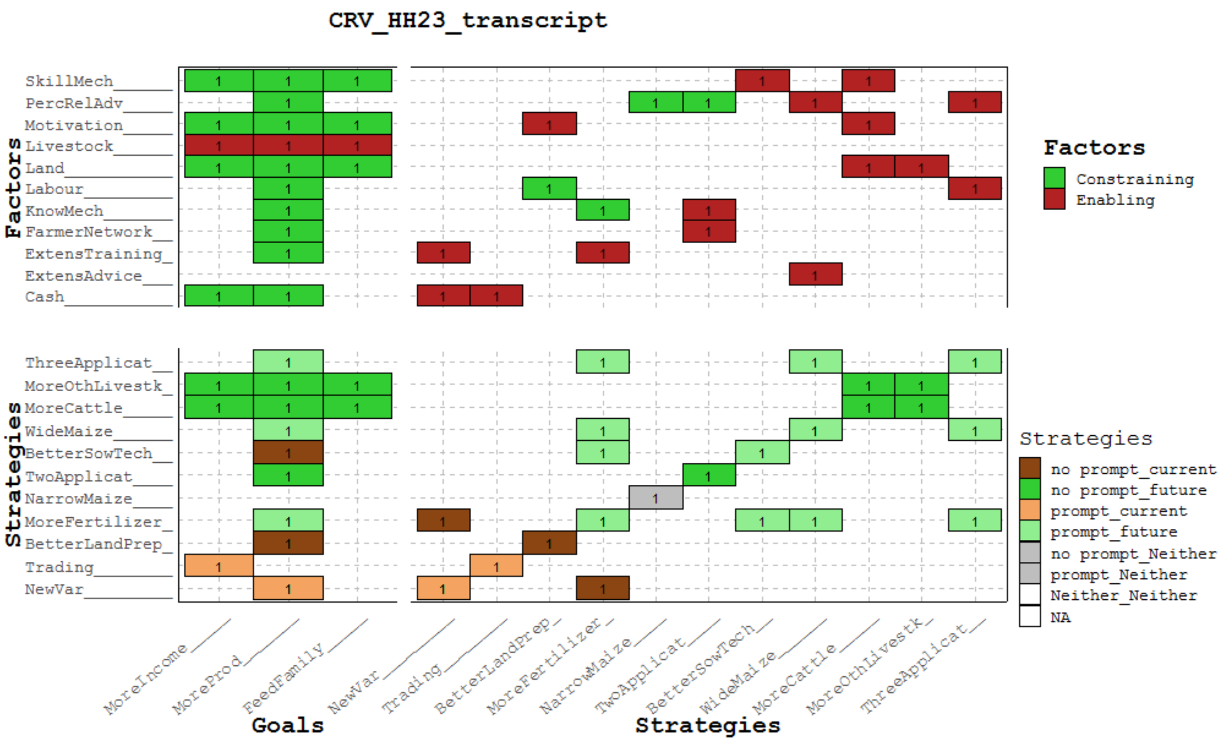

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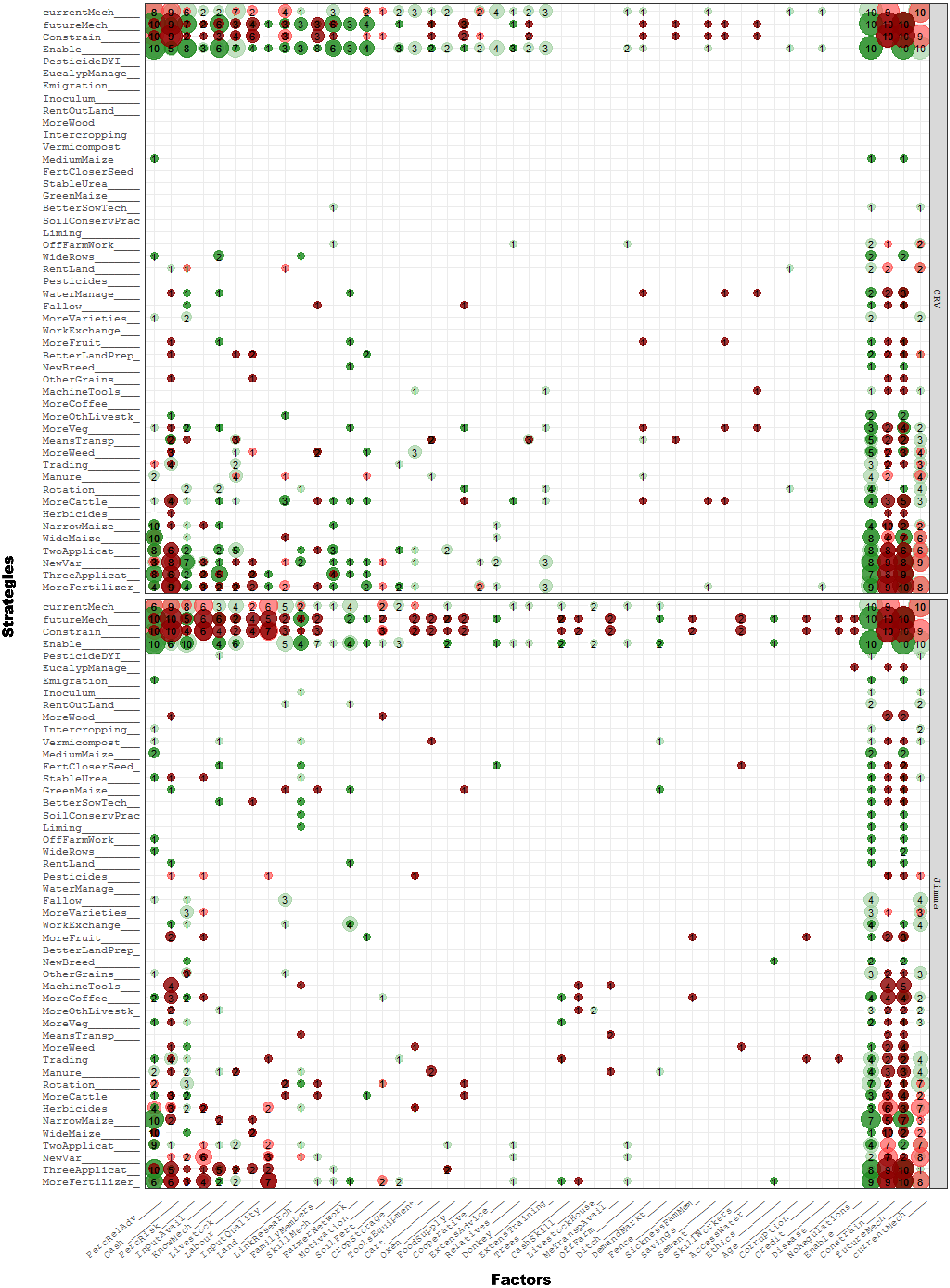
7.7 Co-occurrence matrices of strategies and all factors



7.8 Non-prompted future strategies only