Human Ecology
https://doi.org/10.1007/s10745-023-00413-0

Strategies Steering Intensification Pathways of Farmers in Central Malawi

Carl J. Timler[1] · Jeroen C. J. Groot[1,2,3] · Sieglinde S. Snapp[3,4] · Pablo A. Tittonell[5,6,7]

Accepted: 25 May 2023

Abstract
Smallholder farmers face many challenges to improve their livelihoods and food security. Intensification of agricultural production can help to achieve these goals. Yet farmers are highly heterogenous in their strategies towards intensification, potentially following unsustainable intensification pathways. Using Q Methodology, we ascertain different strategies regarding farm improvement and intensification of smallholder farmers in the Dedza and Ntcheu Extension Planning Areas in Central Malawi. These strategies were associated to coherent sequential choices as expressed in "managerial intensification pathways" (MIPs). Three main strategies emerged: Seed Saving Peasants, Aspirant Modern Farmers and Entrepreneurial Business(wo)men. These were subsequently linked to four MIPs. Seed Saving Peasants focus strongly on local seed systems and post-harvest protection of grains, but also allocate more labour to improving crop residue use and manure quality, thus pointing to a labour-oriented MIP. Aspirant Modern Farmers willingly adopt hybrid seeds and inorganic fertilizers but require more extension support; these farmers follow a technology-oriented MIP. Entrepreneurial Business(wo)men are early adopters of new technologies and benefit from improved access to market information and suppliers of new technologies and follow a sustainable technology-based or techno-ecological intensification pathway. This study shows that strongly contrasting perspectives on intensification exist among smallholders and it is expected that their preferred intensification choices will have diverging impacts on the sustainability of their farms. A diversity of extension, advice and incentive instruments will be needed to support farmer decision making towards sustainably intensified farms.

Keywords Malawi · Smallholder Farmers · Sustainable Intensification · Q Methodology · Strategies

Introduction

Smallholder farmers manage about 30% of the agricultural land globally, yet produce more than half of the globally consumed food calories (Samberg et al., 2016). Therefore, they are considered as being a crucial category of producers contributing to securing future food supply for a growing global population (Kamara et al., 2019). Simultaneously their livelihoods in terms of income, nutrition and equity should be improved. Smallholder farmers often aim to combine the objective of producing food, fuel and fibres for subsistence with the objective of generating income from sales of crop or animal products from their farms (Valbuena et al., 2015). Farm performance regarding both objectives can be improved by

✉ Carl J. Timler
carl.timler@wur.nl

[1] Farming Systems Ecology, Plant Sciences Group, Wageningen University, PO Box 430, 6700 AK Wageningen, The Netherlands

[2] Alliance of Bioversity and CIAT, Development Impact Unit, Viale dei Tre Denari, 472/a, 00054 Maccarese (Fiumicino), Italy

[3] Sustainable Intensification Program, International Maize and Wheat Improvement Center (CIMMYT), Carretera México-Veracruz, Km. 45, El Batán, 56237 Texcoco, México

[4] Department of Plant, Soil and Microbial Sciences, Michigan State University, East Lansing, MI, USA

[5] Instituto de Investigaciones Forestales y Agropecuarias de Bariloche (IFAB), INTA-CONICET, Modesta Victoria 4450 - CC 277, 8400 San Carlos de Bariloche, Río Negro, Argentina

[6] Agroécologie et Intensification Durable (AïDA), Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Université de Montpellier, 34000 Montpellier, France

[7] Groningen Institute of Evolutionary Life Sciences, Groningen University, PO Box 11103, 9700 CC Groningen, The Netherlands

Published online: 30 June 2023

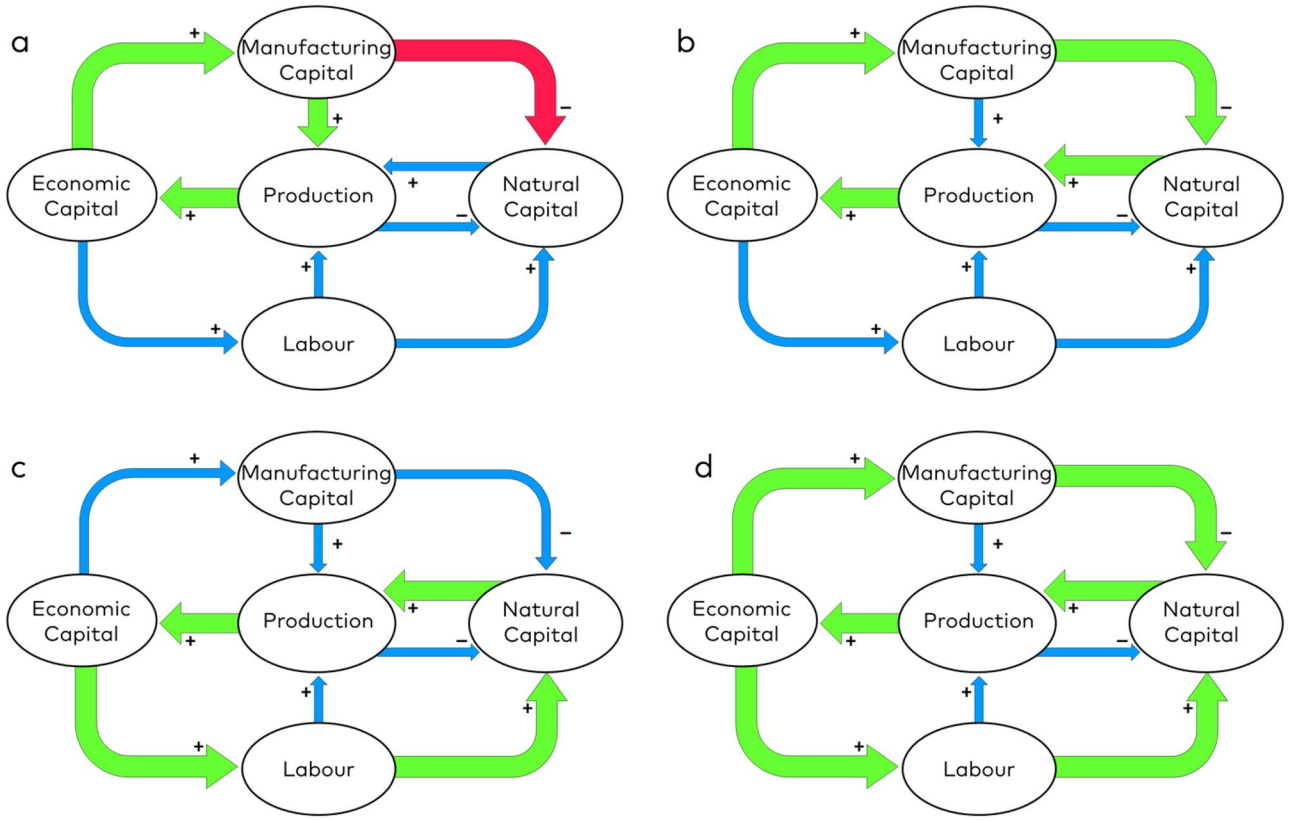

Fig. 1 Contrasting managerial intensification pathways: **(a)** technological intensification (TI) based on high levels of artificial inputs disregarding natural capital, **(b)** sustainable technology-based intensification (STI) based on technologies enhancing natural capital, **(c)** labour-based intensification (LBI) based on labour and enhancing natural capital, and **(d)** integrated techno-ecological intensification (TELI) as a combination of sustainable technology- and labour-based intensification greatly enhancing natural capital. Thicker green (positive) and red (negative) arrows designate dominant interactions, while thin blue arrows designate processes that are less dominant

efficiently increasing the production volume. The production volume can be increased by expanding the farm area (extensification), but, in Malawi, lack of available land constrains this extensification (Potts, 2006; Ricker-Gilbert et al., 2014). Peter et al. (2018) state that, in Malawi's recent past, extensification had occurred, however options for any further extensification in Malawi were limited to protected or marginal areas unsuitable for production barring substantial input investments. Therefore, the remaining option is for farmers to attempt to intensify their agricultural production. Options for intensification are to i) produce mixtures of crops (intercropping), or other crops or animal species that are more productive or nutritious, ii) cultivate the same area of land multiple times per year when biophysical conditions and input availability allow, or iii) boost the productivity of individual crops by increasing inputs levels, improving management practices and reducing yield-limiting factors. (Mungai et al., 2016; Snapp et al., 2018).

Farm productivity and attempts to intensify production are mediated and influenced by three important factors: biological processes and natural resources that support production, external inputs and technologies that are used, such as seeds, fertilizers, pesticides, feeds, veterinary care, machinery, etc., and the quantity and quality of labour for management of crops and animals. These three factors, represented by natural capital, manufacturing capital and labour respectively in Fig. 1, interact. For instance, more skilled and knowledgeable labour input can contribute to better management of the natural resources and more efficient use of inputs. Greater focus on improvement of natural capital can enhance nutrient cycling and biocontrol on the farm, hence reducing the need for external inputs. The availability of these external inputs also depends on farmers' access and investment opportunities which would be represented by economic or financial capital.

From a farm management perspective, the main entry points for intensification are through the quantity and quality of labour (labour-based intensification) and the utilization of inputs and technologies (technological intensification) (Van der Ploeg, 2013; Van der Ploeg & Ventura, 2014). We hypothesize that, on the basis of the interactions among these production factors, four conceptual managerial

intensification pathways (MIPs) can be distinguished. The first pathway of technological intensification (TI) can be primarily based on technologies that have short-term benefits but do not support the build-up of natural capital of the farm, leading to a reduction over the longer term (Fig. 1a). Technological intensification can be more sustainable (STI) by using technologies and practices to build and protect natural resources in both the short and long term (Fig. 1b). Alternatively, a labour-based intensification pathway (LBI) mostly seen in peasant farms is essentially focusing on limiting input use (economical farming) and strengthening biological processes to improve production over time (Fig. 1c). As a final strategy, an integrated techno-ecological intensification pathway (TELI) that uses aspects of sustainable technological intensification (Fig. 1b) and labour-based intensification (Fig. 1c) could be envisioned for both short- and long-term improvements in production (Fig. 1d). Van der Ploeg and Ventura (2014) highlight that farmers' strategic behaviour influences their yields and the productivity of their land, and that smallholder farmers are a key area on which to focus on improving world food production. The rates at which these strategies influence natural, manufacturing and economic capitals can vary, potentially encouraging farmers to choose pathways that provide quicker returns, rather than those with slower rates of improvement.

Insight into the intensification pathways, and the sustainability of these pathways, is essential to establish the requirements of farmers to improve the productivity of their enterprises and to anticipate the potential impacts of farm development on socio-economic and environmental dynamics. This can be performed through participatory research into these dynamics that advises policy development. Farming systems are highly heterogeneous with different biophysical conditions, market access and family stage and aspirations (Alvarez et al., 2018). An intensification pathway provides a dynamic perspective on this diversity and farmer requirements in terms of inputs, market access and information and other support.

Although the need for intensification is widely articulated there are large concerns over the sustainability of agriculture, due to high levels of inputs and inefficient use of these inputs that results in degradation of natural resources, environmental pollution and consequently overshooting of planetary boundaries (Rockström et al., 2017). Therefore, there is a strong incentive to develop novel strategies and pathways that are more sustainable (Pretty et al., 2011).

Farmers adapt and improve their farm enterprise to better meet their aspirations within contextual constraints and influences that are shaped by, amongst others, the availability of farm resources, the biophysical environment and the socio-economic conditions and policies. The sequence of adaptations is based on strategic choices. A strategy can be understood as an approach that affects the farm, is informed by both short and/or long-term objectives and governs the selection of practices and technologies (Ackoff, 1990). We assume that a logical, coherent strategy shapes the farm development pathway or trajectory. Smallholder farmers in Central Malawi who combine subsistence and entrepreneurial objectives, while facing the constraints of lack of functional markets and land and input scarcity that hinder them from making productive use of their limited resources, are in urgent need of further improvements in the development of their farms and livelihoods. To inform this development and gain insight into the strategies and intensification pathways that these farmers use, the objectives of this study were to inventory and analyse different farmers' strategies regarding farm improvement and intensification. Furthermore, we ascertain whether these strategies could be associated to coherent sequential choices as expressed in the four managerial intensification pathways. To this end this study also contributes towards the sustainable intensification of smallholder agriculture, and can inform relevant approaches for tailoring and upscaling these innovations for smallholder farmers in Malawi.

Methodology

This study was part of the AfricaRISING project (Africa Research Into Sustainable Intensification for the Next Generation), a Research for Development project that was active in Malawi, Tanzania, Ethiopia, Ghana and Mali. The project aimed at sustainably intensifying smallholder farming systems using a basket of novel technologies and techniques. These were introduced through participatory action research methods and by facilitating co-creation and co-learning between farmers and researchers (http://africa-rising.net/).

The study sites of the AfricaRISING project in Central Malawi were in the Dedza and Ntcheu Extension Planning Areas (EPAs). In each EPA, two districts were chosen, Linthipe and Golomoti in Dedza, and Nsipe and Kandeu in Ntcheu. In April 2014 and January 2015, for a baseline survey, structural and functional farm and household data from 75 farmer households from the four districts, was collected using semi-structured surveys. Farm households were initially sampled in April 2014 using a Y-frame method (Tittonell et al., 2013) from pairs of villages in each district. Each village pair consisted of an AfricaRISING project intervention and non-intervention site. For this Q Methodology study that took place in June 2017, only 40 out of these 75 farmers were selected as respondents. Equal numbers of farmers from the four districts were selected for the Q methodology study. The farmers were selected such that the selected population had farmers with a range from high to low of the following characteristics: land sizes, incomes, expenditures and livestock numbers. The Social Sciences Ethical Committee of Wageningen

University granted ethical approval and waived the need for informed consent for this study. Oral consent to participate in this study was still obtained from the selected farmers[1] and this study was carried out following all the relevant guidelines and regulations.

The four MIPs (Fig. 1) including explanatory examples were presented to a panel of four experts[2] in the field of Malawian smallholder agriculture who expressed their opinion that these intensification pathways matched the reality of smallholder farmers in Central Malawi. Q Methodology (Stephenson, 1935; Watts & Stenner, 2005) was used to ascertain the strategies of the farmers. A set of statements, known as a Q-set, was generated by the researchers and was presented to the panel of experts. These generated statements were related to the four MIPs, farm management and decision making, the opportunities and constraints, and the likely order of implementation, of novel intensification technologies and practices. The expert panel, together with the researchers edited and reduced the number of statements until no more changes were suggested. Q Methodology uses inverted factor analysis (Stephenson, 1935), looking for correlations between subjects over a sample of variables, as opposed to R studies, like statistical typologies, where correlations are sought between variables over a sample of subjects. It is thus recommended in Q studies to have fewer participants than statements (Forrester et al., 2015; Watts & Stenner, 2005). However, some studies such as Nordhagen et al. (2017) and Zabala et al. (2017) have had fewer statements than respondents.

The final 52 statements (in English and translated into Chichewa) were printed onto cards. A grid was used to arrange assorted cards (Fig. 2) and participants were asked to arrange the statements in it according to the strength with which they agreed or disagreed with the statements. The participants initially sorted the cards into three piles namely; 'agree with', 'disagree with' and 'neutral'. Then they gradually worked through the two non-neutral piles to divide them further into three (or more) piles, arranging the printed cards on the grid. Illiterate respondents needed the statements read out aloud to them. Nordhagen et al. (2017) found no differences between the results of literate or illiterate respondents. Malia and Bennett (2011) indicate that the presence of the researcher during the Q-sort could unconsciously influence the participant's responses though.

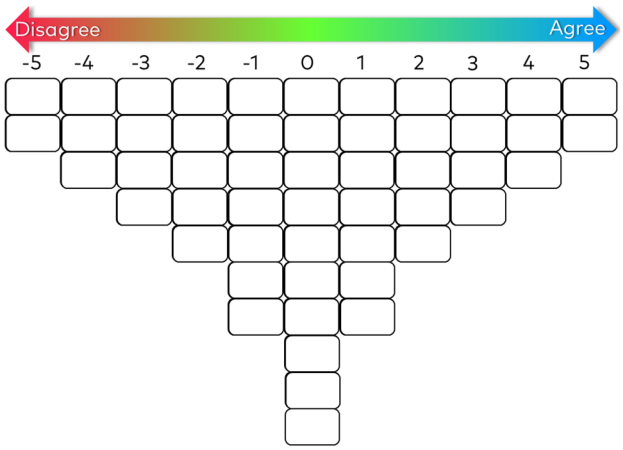

Fig. 2 Quasi-normal distribution table used for Q-sorting. The grid positions on the left (negative numbers) are sorting positions for statements that participants disagreed with, while grid positions on the right (positive numbers) are sorting positions for statements that participants agreed with. The proximity to 5 or -5 shows the strength of agreement or disagreement respectively

Each Q-sort was followed by post-hoc questioning to discover any errors or misunderstandings, and to get a deeper understanding of the participant's reasons for sorting the statements as they did. The post-hoc interviews were also later used to affirm the results from the statistical analysis.

After the Q-sorts were performed, a matrix was composed of the 52 statements (rows) and the 38 Q-sorts (columns). This matrix was used in the statistical analysis which was performed in the R environment using the package qmethod (Zabala, 2014). Pearson's Method was used to examine correlations between Q-sorts.

The analysis in R Statistics (R Core Team, 2022) included the following statistical results; Q-sort factor loadings, flagged Q-sorts, statement z-scores, statement factor scores, general factor characteristics (average relative coefficients, number of Q-sorts loading per factor, eigenvalues, explained variance, reliability and standard error of the f-scores), correlation between factor z-scores, standard error of differences between factors and finally the distinguishing and consensus statements per factor. This analysis was performed with varying numbers of factors and a final choice was made based on the general factor characteristics, as to how many factors to extract. Each factor representing a separate strategy.

The statements that were distinguishing for each factor informed the narrative for the various strategies for sustainable intensification of the farmers. The loadings of these statements were aggregated and mapped onto the representation of the discourse (Fig. S1). The results of the Q methodology were qualitatively described by these narratives, and indicated which types of farmers follow which strategies and thus which managerial intensification pathway they would follow.

[1] One selected farmer did not give consent, so a replacement farmer was selected in the same village. Two selected farmers began, but did not complete the sorting, and were not replaced. This resulted in 38 completed Q-sorts.

[2] Two agronomists, a systems analyst and a Malawian extension worker who were familiar with the project and the study sites.

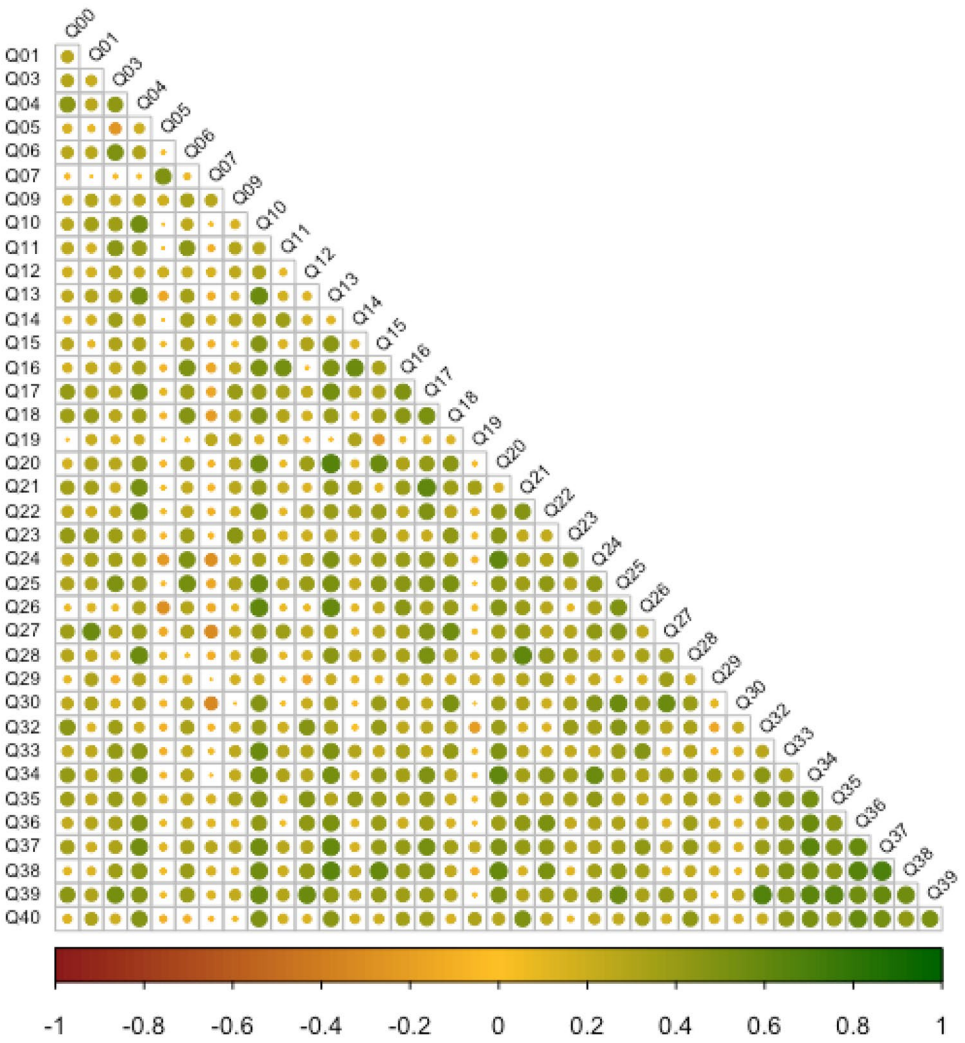

Fig. 3 Correlation heatmap of the 38 Q-sorts performed in Dedza and Ntcheu, Central Malawi, June 2017. Size of circles and their colour indicate the strength and direction of the correlations

Results

High correlation between the Q-sorts Q32 to Q40 in Linthipe EPA in Dedza district reflected that these farmers had similar levels of agreement or disagreement on similar statements. There was poor correlation between the three Q-sorts; Q05, Q07 and Q19, and almost all other Q-sorts indicating that these farmers differed in their strategies to all other sampled farmers (Fig. 3).

The Number of Extracted Factors

There are a number of general factor characteristics that can be examined in order to choose the number of factors to extract; eigenvalues that are greater than one, the explained variance of the factors, the number of flagged Q-sorts per factor and the number of unflagged[3] Q-sorts. These general factor characteristics are presented in Table 1.

Due to there being more unflagged Q-sorts, lower eigenvalues and less explained variance when extracting four factors, than when extracting three factors, it was decided to perform the analysis using three extracted factors. In the following section the factors will be described with regard to the statements that distinguish them.

In Fig. 4 we present the individual Q-sorts clustered according to their loadings for the three factors. Two Q-sorts (participant farmers) flagged as factor 3 (blue) were not clustered with the others. These two farmers are Q5 and Q7, which were not correlated well with other Q-sorts (Fig. 3). These two farmers were less endowed in terms of production resources when compared to other farmers in this cluster. Their views on the distinguishing statements were diametrically opposed to those of others who are clustered in this factor.

Factor Descriptions

On the basis of the calculated z-scores, all the statements and their factor scores are presented in Table S1 in the

[3] Unflagged Q-sorts have no clear affiliation to one factor, rather have strategies matching more than one factor.

Table 1 Output from the call qmethod highlighting differences in three general factor characteristics; number of loading Q-sorts, Eigenvalues and Explained Variance when performing the analysis of the Q-sorts with three, or with four extracted factors in R. The final analysis used three extracted factors

General factor characteristics	Three extracted factors	Four extracted factors
Number of Q-sorts loading		
Factor 1	16	15
Factor 2	11	7
Factor 3	7	4
Factor 4		3
Number of unflagged Q-sorts	4	9
Total Q-sorts	38	38
Eigenvalues		
Factor 1	8.3	7.8
Factor 2	5.1	5.1
Factor 3	4.4	4.1
Factor 4		3.1
Explained Variance		
Factor 1	22.0	20.5
Factor 2	13.0	13.4
Factor 3	11.0	10.8
Factor 4		8.2

Supplementary Material. This indicates the arrangement of the Q-sort typical to a respondent belonging to each factor. To highlight the differences between the factors the statements that distinguish each factor are presented in Table 2. Distinguishing statements have significantly different z-scores (cf. Fig. S2). The statements in the q-concourse were mapped onto the managerial pathways from Fig. 1 and shown with positive or negative relationships according to the factor scores for the statements of the three factors (Fig. 5).

Factor 2 – "Autonomous Seed Saving Peasants"

The farmers who followed this strategy strongly agreed (+5) that saving seeds would enable them to save money and this strong agreement with statement 31 "*Saving seeds to replant them the following season is a good strategy for me to save money*" distinguishes them from the other two factors. Furthermore, they disagreed (-4) with statement 32 "*Investing my money in buying new hybrid maize seed every year is something I would do*" indicating their unwillingness to have to purchase hybrid maize seeds annually. Additionally, that the slight disagreement (-2) with statement 30, "*I would rather plant local maize varieties than hybrid maize varieties*" was distinguishing for this factor, in addition to the fact that they disagreed less than the other two factors with regards to this statement (cf. Table S1), further strengthened their view on this strategy and desire for autonomy with regards to seed self-sufficiency. The fact that, in the rural areas of central Malawi, (hybrid) seeds are usually not available on time, or are sold out at planting time, in addition to their financial constraints, are strong driving forces for these farmers to want to save seed. Having their own seed allows them to plant at precisely the right time.

They strongly agreed (+5) that mineral fertilizers are better than compost or manure. For statement 18, "*Mineral fertilizer is better than animal manure or compost for improving the fertility and quality of my soil*", each factor had a significantly different viewpoint. Their strong agreement, is diametrically opposed to that of the third factor (-4) described below, and could be indicative of a desire by the respondents to be seen to be positive towards the use of mineral fertilizers in the hopes of receiving more inputs from funded programs. Alternatively, this positive viewpoint on mineral fertilizers might stem from the desire for a critical quick win to compensate for a lack of animal manures. They furthermore, would be prepared to work harder to achieve their goals as shown by the strength of their agreement (+4) for statements 7, "*If I have no money to invest in my farm, I will work more/longer hours on my farm to achieve better yields*" and 13, "*I usually try to improve my harvest by working hard to plant and weed carefully and on time*" and their disagreement (-4) with statement 3, "*A lack of (family) labour prevents me from making any changes in the way I farm*". In Fig. 5a, this can be seen by the strong pathways between Labour and Natural Capital, and between Natural Capital and Economic Capital. They were distinguished by their neutrality on statement 23, "*If I have no money to invest in my farm, I will work on other farms*" showing that they had no desire to invest their labour on other's farms.

The "Autonomous Seed Saving Peasants" strongly disagreed (-5) with statement 15, "*I would rather burn my maize residues than incorporate them into the soil as this saves me labour*" (as do all factors), however for this factor, it was a distinguishing statement. Possibly further indicating a willingness to be seen to be complying with the knowledge that this is a negative practice. Agreement (+2) with the distinguishing statement 19, "*I think that digging a pit for manure storage and building a roof over it, is worth the labour and material costs it requires as the manure will have better quality*" indicated some interest from this factor in adopting innovations regarding the building of improved manure storage systems and more efficient use of on-farm produced organic resources. During post-hoc interviews, farmers asked for more detailed descriptions of such structures, as well as indicated a desire to be taught how to construct them.

They disagreed strongly (-5) with statement 43, "*I prefer to sell my farm products and buy food for my family rather than produce our own food*", however, conversely

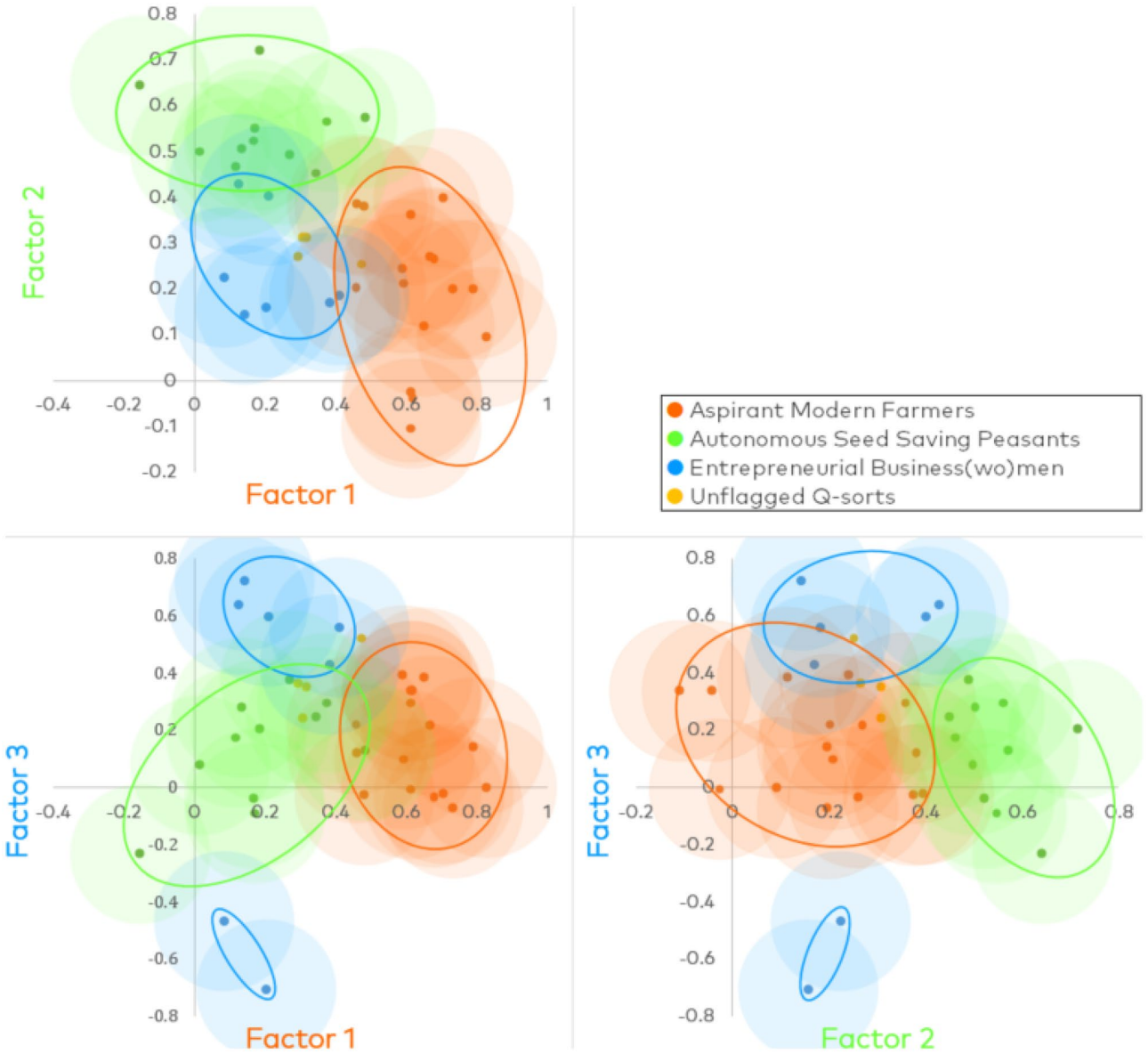

Fig. 4 Q-sorts displayed according to their loadings for the three factors. Ellipses around clusters of points are hand drawn

also disagree (-3) with statement 51, "*I would rather eat the vegetables I produce, than sell them to buy other food*". This can be explained by the interpretation of "*farm products*" by the respondents to only mean maize, and that fact that maize is traditionally viewed as a crop that you would only keep to eat, whereas vegetables are perishable, temporarily in oversupply, and are hence used to generate income.

Their agreement with the statement regarding using PICS storage bags distinguished them from the other two factors. These farmers were not market oriented, and were concerned about post-harvest losses. Farmers who were interested in these bags, saw the benefits in the re-usability of the bags despite their higher initial investment costs. Preferring a once-off investment in PICS storage bags, as opposed to on-going chemical purchases. These viewpoints further indicated their desire for reducing their dependence on external inputs.

Factor 1 – "Aspirant Modern Farmers"

The farmers who followed this strategy strongly agreed that they want their children to take over their farm. To some degree, this is a cultural characteristic of all these smallholder farmers (but particularly of the farmers in the Linthipe district). Their strong feelings towards this statement were also reflected in comments in their post hoc interviews where they stated a desire to look after the land so that their children would not inherit degraded lands, nor have

Table 2 Distinguishing statements for each factor; "Autonomous Seed Saving Peasants" (Factor 2), "Aspirant Modern Farmers" (Factor 1) and "Entrepreneurial Business(wo)men" (Factor 3) in order of endowment from low to high respectively

"Autonomous Seed Saving Peasants"		"Aspirant Modern Farmers"		"Entrepreneurial Business(wo)men"	
5	Saving seeds to replant them the following season is a good strategy for me to save money	4	To produce more food I only need to use more fertilizer	1	Hiring extra labour means I can work less
2	Using PICS grain storage bags is something I would do to reduce post-harvest losses	3	A lack of access to extension prevents me from making any changes in the way I farm	1	Using post-harvest storage chemicals (like Actellic) is something I would do to reduce post-harvest losses
2	I think that digging a pit for manure storage and building a roof over it, is worth the labour and material costs it requires as the manure will have better quality	3	I think that hybrid maize seed is a good way to produce more food or earn more money	-1	I would plant Orange Fleshed Sweet Potatoes on my farm
1	I would invest extra labour to incorporate maize residues into the soil because it improves the soil quality	0	A lack of (family) labour prevents me from making any changes in the way I farm	-1	If I earned money from non-farm work I would invest it in my farm
0	If I have no money to invest in my farm, I will work on other farms	0	Growing doubled up legumes (e.g. Groundnuts and Pigeon peas planted together in the same field) is something I would do	-2	Spending more of my time weeding (more than what I already do), is something I would do to improve yields
-2	I would rather plant local maize varieties than hybrid maize varieties	-2	Keeping pigs would be a good business to run and is something I would do		
-4	Investing my money in buying new hybrid maize seed every year is something I would do	-4	If I produced more maize, I would rather sell it, than use it to feed my family		
-5	I would rather burn my maize residues than incorporate them into the soil as this saves me labour	-5	Planting a crop like tobacco to sell for cash is a better way to ensure food security than growing a food crop		

Numbers to the left of each statement indicate the factor scores for each statement for each factor, indicating the typical score a respondent belonging to that factor would have chosen for that statement. Scores range from 5, very strongly agree, through 0, which is neutral, to -5, which is very strongly disagree

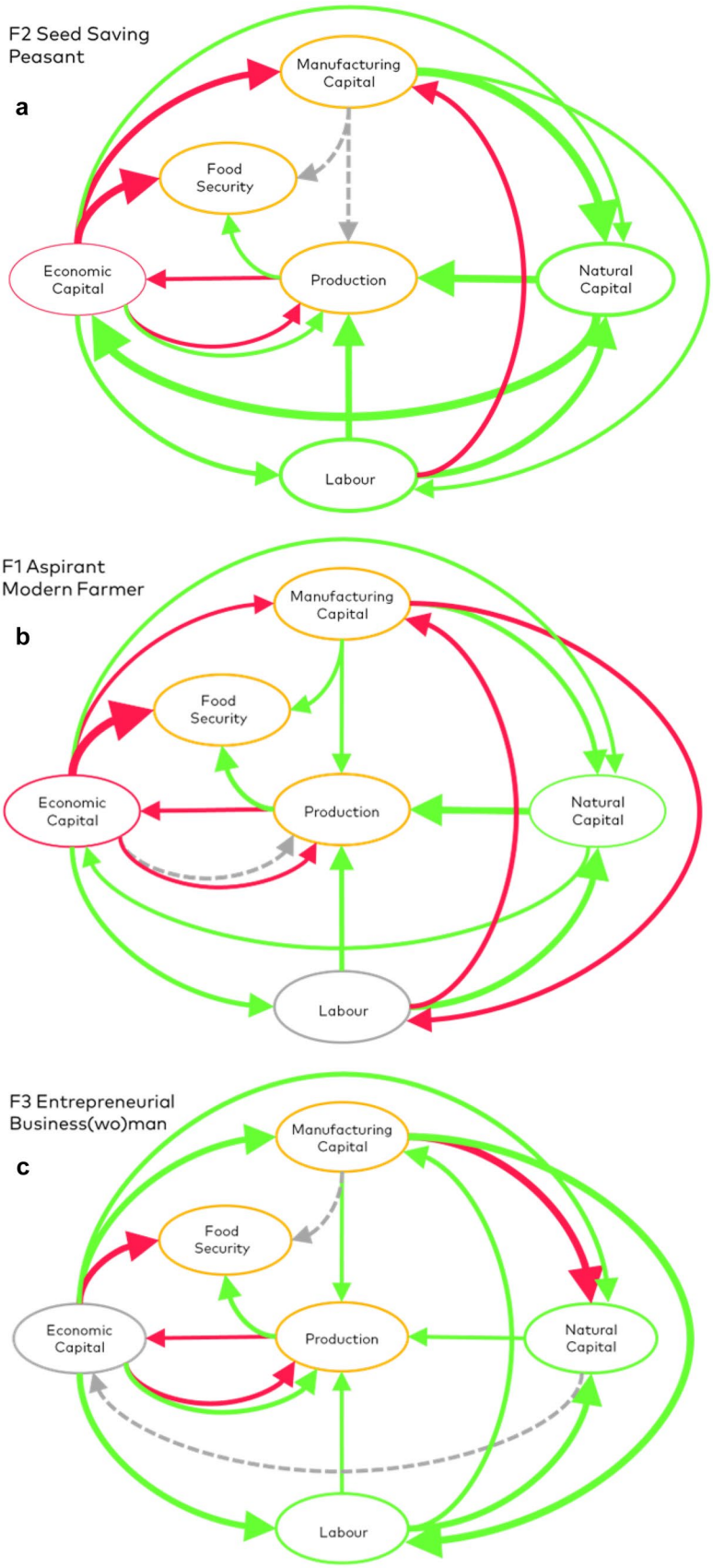

Fig. 5 Mapping of factor loadings onto relations identified in the Q concourse (see also Fig. S1 for explanation of the relationships). Red arrows indicate disagreement, green indicate agreement and grey arrows are neutral. The width of the arrow indicates the relative strength of the loading for each relation. The strategies are ordered from low (**a**) to high (**c**) resource endowment

to struggle to find land to cultivate. This strategy was also reflected in the other strongly agreed with (+5) statement, "*I would invest extra labour to incorporate maize residues into the soil because it improves the soil quality*". In turn, this strategy was still further strengthened with a strong disagreement (-5) with statement 15, "*I would rather burn my maize residues than incorporate them into the soil as this saves me labour*". In Fig. 5b, a strong relationship is therefore mapped between Labour and Natural Capital. Their disagreement (-3) with statement 25, "*If I have no money to invest in my farm, I would look for a non-farming job*", showed their attachment to, and desire to work on and improve, their own farm.

These farmers indicated themselves not being particularly labour-constrained. This was shown by statement 3, "*A lack of (family) labour prevents me from making any changes in the way I farm*", which was a neutral and distinguishing statement for factor 1. However, their disagreement (-3) with statement 10, "*Hiring extra labour is not something I want to do*" indicated they would not be averse to hiring extra labour. They are diligent, and place importance on timely cultivation practices and the use of purchased inputs such as hybrid seeds, fertiliser and (broad spectrum) insecticides. This was reflected by the scores of +4 for statements 13, "*I usually try to improve my harvest by working hard to plant and weed carefully and on time*", 21, "*To produce more food I only need to use more fertilizer*" and 36, "*Using post-harvest storage chemicals (like Actellic) is something I would do to reduce post-harvest losses*", and scores of +3 for statements 33, "*I think that hybrid maize seed is a good way to produce more food or earn more money*" and 32, "*Investing my money in buying new hybrid maize seed every year is something I would do*". However, they felt challenged, or held back by a lack of extension; statement 5 "*A lack of access to extension prevents me from making any changes in the way I farm*" being a distinguishing statement for this factor. They were also distinguished by their neutral feelings towards statement 44, "*Growing doubled up legumes (e.g. Groundnuts and Pigeon peas planted together in the same field) is something I would do*" reflecting a lack of interest in adopting this innovation widely promoted by the AfricaRISING project.

The "Aspirant Modern Farmers" would be adverse to planting only a cash crop and purchasing food with the profits, shown by their strong disagreement (-5) with the distinguishing statement 41, "*Planting a crop like tobacco to sell for cash is a better way to ensure food security than growing a food crop*", and their disagreement (-4) with the distinguishing statement 42, "*If I produced more maize, I would rather sell it, than use it to feed my family*" as well as statement 43, "*I prefer to sell my farm products and buy food for my family rather than produce our own food*". In Fig. 5b, this is mapped as a strong negative relationship between Economic Capital and Food Security. They were further distinguished by their disinterest in keeping pigs as a business as shown by their disagreement (-2) with statement 28, "*Keeping pigs would be a good business to run and is something I would do*" when compared to the positive scores for this statement from the other two factors.

Factor 3 – "Entrepreneurial Business(wo)men"

The farmers following this strategy agreed strongly (+5) with statement 12, "*Purchasing herbicide to kill weeds makes sense because it would save me labour*", and statement 39, "*Buying a treadle or motorized pump to irrigate my crops is a good investment of my money*". Both these viewpoints indicated a more entrepreneurial, business-like approach to farming. This was further supported by the agreement (+4) with statements 28, "*Keeping pigs would be a good business to run and is something I would do*" and 24, "*If I have no money to invest in my farm, I will attempt to take out a small loan or sell my livestock*". The majority of the farmers that load for this factor would be regarded as well resource endowed farmers, and included the farmers with larger numbers of tropical livestock units (TLU's). The agreement (+3 and +2) with statements 16,"*I would like to use machines to reduce my labour load*" and 40, "*If I had enough money to purchase a two-wheel tractor, I think that this would be a good investment of my money*" respectively, indicated an interest from these farmers in mechanization. This was further supported by their strong agreement (+5) with statement 39 as mentioned previously. Small scale mechanization was therefore a desired intensification option of the farmers with this strategy as can be seen by their unique strong relationship between Manufacturing Capital and Labour in Fig. 5c.

The "Entrepreneurial Business(wo)men" strongly disagreed (-5) that local maize is better than hybrid maize, indicating their strong preference for hybrid maize varieties. Modern seeds are purchased annually according to the post-hoc interviews. Some received FISP[4] subsidized hybrid seed and others not. They also disagreed strongly (-5) (as did all factors) with statement 15, "*I would rather burn my maize residues than incorporate them into the soil as this saves me labour*". Their disagreement (-4) with statement 18, "*Mineral fertilizer is better than animal manure or compost for improving the fertility and quality of my soil*" was significantly different from the other two factors and reflected a

[4] Farm Input Support Program through which the least resource endowed farmers are provided subsidized access to agricultural inputs like hybrid seeds and fertilizers, although not always in a timely manner.

Table 3 Consensus statements for all three factors; "Autonomous Seed Saving Peasants" (Factor 2), "Aspirant Modern Farmers" (Factor 1) and "Entrepreneurial Business(wo)men" (Factor 3) in order of endowment from low to high respectively

Statement	"Autonomous Seed Saving Peasants"	"Aspirant Modern Farmers"	"Entrepreneurial Business(wo) men"
I usually try to improve my harvest by working hard to plant and weed carefully and on time	4	4	3
The extra labour it takes to cut and bring high quality fodder to feed an animal well, is worth the additional manure (and/or milk) it produces	0	0	0
I would invest my money to purchase livestock in order to get manure	1	1	2
Breeding and selling local chickens is a good source of income and is something I would do	1	2	1
To improve my the nutrition of my family, I would plant Groundnuts and Pigeon peas for them to eat	2	2	2
Groundnuts and Pigeon peas are good crops to make money with	0	1	0
Reducing post-harvest losses is a good strategy to ensure food security	0	1	0
Planting vegetables to sell is something I would do to earn extra money	0	-1	-1

Numbers indicate the factor scores for each statement for each factor, indicating the typical score a respondent belonging to that factor would have chosen for that statement. Scores range from 5, very strongly agree, through 0, which is neutral, to -5, which is very strongly disagree

more nuanced viewpoint on the longer-term benefits of compost on soil fertility. These farmers also disagreed (-4) with statement 48, "*I would include a doubled-up legume crop (where two bean-like plants are intercropped) on a third of my fields*", and in some of the post-hoc interviews it was mentioned specifically that the combination of pigeon pea and groundnut was not favourable. Reasons given were that the pigeon pea plants were uprooted during the harvest of the groundnuts. This factor was also distinguished by their slight disagreement (-1) for growing orange-fleshed sweet potatoes, compared with neutral viewpoints for other factors.

Regarding their strategies towards labour, a distinguishing statement agreed with (+1) by this factor was statement 9, "*Hiring extra labour means I can work less*". In combination with their agreement (+4) with statement 46, "*I would invest extra labour to incorporate maize residues into the soil because it improves the soil quality*", and the agreement (+3) with statement 8, "*If I made extra money selling crops, I would consider hiring labourers to do extra work (e.g. weeding or land preparation) on my farm*", indicated that they have the means and the preference to hire labourers. This was supported further by their disagreement (-2) with the distinguishing statement 11, "*Spending more of my time weeding (more than what I already do), is something I would do to improve yields*" and disagreement (-2) with statement 10, "*Hiring extra labour is not something I want to do*".

There were two distinguishing statements that were somewhat incongruous with the strategy of a business-like farmer. Statement 36, "*Using post-harvest storage chemicals (like Actellic) is something I would do to reduce post-harvest losses*" is only slightly agreed with (+1) by this factor, compared with much stronger agreement (+4) and (+3) from factors one and two respectively (cf. Tables 2 and S1). This might indicate a desire to use other options to reduce post-harvest losses, yet statement 34, "*Building an improved granary is something I would do to reduce post-harvest losses*", and statement 35, "*Using PICS grain storage bags is something I would do to reduce post-harvest losses*", were also only slightly disagreed with (-1) and neutral respectively. This possibly indicated that they did not perceive post-harvest losses to be a major challenge. The other incongruous, yet distinguishing statement, was statement 26, "*If I earned money from non-farm work I would invest it in my farm*", with which they slightly disagree with (-1). It would seem to make more sense for a business-minded entrepreneurial farmer to have agreed more strongly with this statement. However, it could also indicate that they did not perform off-farm work, earning enough through their own farm business.

A number of statements were in consensus between the three factors, for these statements all three factors had a similar perspective on these strategies. These statements are presented in Table 3. All farmers agree that they work hard and conscientiously, and that legumes such as Groundnuts and Pigeon Peas can improve nutrition. Small livestock such as chickens are seen to be potentially interesting for their manure with slight agreement, whereas income generation with legumes and marketable vegetables has neutral to slight disagreement. The neutral perspective on collecting fodder could be due to the lack of large livestock held by these farmers.

The Q methodology discourse statements were mapped onto the representation of strategies (Fig. S1). In Fig. 5, the average factor scores are indicated in this mapping for the three Q factors. Some of the major trends we can observe are the following. Farmers in all factors would prefer to grow their own food to improve their food security (red arrow

Table 4 Averages of farm and household variables (standard deviation in parentheses) for the farmers in the three different factors, in order of endowment from low to high, collected from semi-structured survey data in January 2015

Variables	*Factors*		
	2 "Seed Savers" n = 11	*1 "Modernists"* n = 16	*3 "Business(wo) men"* n = 7
Gross Margin (US$ year^{-1})	184.48 (233.10)	220.96 (856.30)	362.79 (606.10)
Off-farm income (US$ year^{-1})	284.62 (337.45)	325.60 (578.68)	552.81 (803.75)
Total income (US$ year^{-1})	405.18 (296.96)	580.34 (942.10)	862.73 (767.87)
Total Expenditure (US$ year^{-1})	220.69 (148.39)	379.38 (289.28)	499.93 (381.39)
Tropical Livestock Units (TLU)	0.11 (0.20)	1.26 (2.10)	2.31 (3.53)
Yields (kg ha^{-1})	997 (531)	1211 (1127)	2023 (2584)
Land owned (hectares)	2.32 (1.23)	2.09 (1.78)	3.27 (3.43)
Land farmed (hectares)	2.25 (1.18)	2.06 (1.58)	3.28 (3.37)
Land allocated to food crops (hectares)	1.66 (0.82)	1.69 (1.43)	2.29 (1.82)
Land allocated to cash crops (hectares)	0.60 (0.45)	0.37 (0.43)	1.04 (1.56)

between economic capital and Food security). "Aspirant Modern Farmers" are not labour constrained (labour is neutral), and thus they place less importance on technologies to save labour. "Seed Saving Peasants" agree more with using manufacturing capital (new low-cost technologies) to increase natural capital hence reducing costs to improve economic capital. "Entrepreneurial Business(wo)men" agree with adopting technologies to save labour, and improvement of economic capital is less reliant on improved natural capital.

Comparison with Farm and Household data

Structural and functional farm and household data of farmers allotted to the factors (Table 4) showed a numerical trend, indicating that that "Entrepreneurial Business(wo)men" had the most favourable financial indicators, the highest gross margin, off-farm income and total income, although these differences were not significant. Furthermore, this trend extended to their numbers of animal units and land sizes, which tended to be larger than the other factors. The high values of standard deviations and the lack of significance of differences indicate a large variability in structural and functional farm features within Q factors. This could indicate that the factors are not strictly related with resource endowment levels, and that a farmer with a certain endowment level can have different intensification strategies.

Discussion

The results showed that three distinct and contrasting strategies were held by the smallholder farmers, which emerged from this statistical analysis: "Autonomous Seed Saving Peasants", "Aspirant Modern Farmers" and "Entrepreneurial Business(wo)men". Although not significantly different, trends for average farm incomes, expenditures, yields and TLUs showed higher values for farmers with the "Entrepreneurial Business(wo)men" strategy and lower values for those with the "Seed Saving Peasant" strategy.

These strategies could be linked to the four management intensification pathways presented in Fig. 1 and as such, show that these strategies have diverging impacts on the sustainability of their farms. The diversity of strategies imply that these farmers need diverse, tailored combinations of extension, advice and incentive instruments such as subsidized inputs, to stimulate continuous adoption and support their decision making towards sustainably intensified farms (Mellon Bedi et al., 2022).

Farmers following the "Autonomous Seed Saving Peasant" strategy corresponded to the LBI pathway (Figs. 1c and 5a). They agreed with statements on improving their manure quality by building better manure storage facilities, investing labour in bringing manure to their fields, improving storage using PICS bags and would be more inclined to improve their (poor) financial situation by investing more of their

own labour on their own farm, rather than earning money by working on other farms. These are consistent with the trajectory of the LBI pathway. Fisher and Snapp (2014) found that modern maize varieties may be dis-adopted by Malawian farmers due to their dissatisfaction with performance in drought years and poor storability. They highlighted too, the need for seed breeders to consider the opinions of smallholder farmers on traits they find important in modern varieties. For farmers pursuing the "Autonomous Seed Saving Peasant" strategy, there is need for non-hybrid, improved seeds that allow for the use of saved seed without productivity loss. Due to the relatively weak financial situation of these farmers (Table 4), innovations that improve nutrition, save labour and do not require large financial investments could be initially targeted at these farmers. Transferring knowledge on, for instance, construction methods of improved manure storages in combination with animal husbandry training would be an example of a first step towards intensification. Thereafter, once such farmers experience improved profits from their improved natural capital, logical next steps might include the purchase of PICS bags for better storage of grains to eat and to sow.

Farmers of the "Aspirant Modern Farmer" strategy would correspond to either the TI or STI pathways (Figs. 1a, b and 5a, b). These farmers, although wanting to maintain or improve the quality of their lands for their children, also stated a desire to be modern farmers who use perceived modern agricultural inputs. Adopting (or partly adopting) these intensification technologies could possibly reduce their natural capital, for instance, continued use of chemical fertilizers without organic matter inputs could cause deterioration of soil quality. Their neutral stance towards legume diversification in statements 44 and 48 and investing labour in application of manure in statement 17 (Table S1) show that farmers following this strategy would most likely benefit from improved support from extension with advice and demonstrations of environmentally sound practices. This with the aim of directing these farmers more towards the STI than the TI pathway. Ricker-Gilbert and Jayne (2017) in a survey, found evidence for the complementarity of organic inputs and inorganic fertilizers (e.g. legume integration, manure incorporation and conservation agriculture) as means to increase fertilizer cost effectiveness, profitability and sustainability. Further, another survey by Holden and Lunduka (2012) was consistent with the probability and the intensity of manure use by Malawian farmers as being positively correlated to intensity of fertilizer use. This is suggestive that farmers pursuing the "Aspirant Modern Farmer" strategy could adopt hybrid seeds and fertilizer, as desired modern farming techniques, followed by later steps of increased manure use as well as diversifying their rotations with more legumes, reducing tillage and mulching.

Farmers following the "Entrepreneurial Business(wo)man" strategy corresponded to the STI or TELI pathways (Figs. 1b, d and 5c). They have greater financial resources (Table 4) enabling them to implement new technologies or alternatively, as shown by the two low resource endowed farmers that follow this strategy, (Fig. 4), be prepared to work harder to implement a new technology. They are not constrained by labour (statement 3 in Table S1) and would likely be early adopters and exemplar demonstrators of these new technologies. For these farmers, providing them with access to better information regarding markets for their products can help in improving their economic capital. With improvements in their economic capital, the provision of access to providers of mechanization options could be a logical next step towards intensification. Improved animal husbandry support as well as initiatives to facilitate access to improved breeds would additionally be steps that farmers following this strategy could take provided improvements to the current livestock sector in Malawi can be made.

Walder and Kantelhardt (2018) performed a Q methodological study with Austrian farmers in order to ascertain their viewpoints towards multifunctional agricultural ecosystems. Their comparable study found four viewpoints indicating that agricultural policies should not use a blanket approach but need to take this diversity of mindsets into account. Similarly, in this study, tailored packages should be made available to farmers following these three strategies. Our study used a partly inductive approach, but was supported by the fact that during the construction of the concourse the MIP's were used as reference material for the formulation of many statements. Some further challenges encountered during execution of this methodology were the discovery of a slightly mis-translated statement and that, during the creation of the concourse of statements, the panel of experts could have been more diverse.

The Q Methodological approach used in this study can rapidly determine patterns within heterogenous farmer viewpoints on chosen topics. We believe this to be a useful technique for targeting interventions for the improvement of smallholder livelihoods in many developing countries. This study has shown the use of Q Methodology to rapidly ascertain the diversity of strategies among farmers towards sustainable intensification. Furthermore the added nuance that Q Methodology provides into farmers' strategic choices can inform stakeholders on the diagnosis of the readiness and acceptability of innovations for their scaling (Sartas et al., 2020). Rodriguez-Piñeros et al. (2012) demonstrate that Q Methodology can support farmer engagement allowing their opinions to be ascertained, and thus ensuring community support from small scale farmers in implementing sustainable forest management plans. Furthermore, there is scope for further research into whole farm modelling of the effects on productivity, nutritional, environmental, social and economic indicators, at a

farm level, of the adoption of a range of different innovations, by these three farmer strategies. By creating three farm models of farmers following these strategies, such whole farm models can be used with farmers to examine trade-offs and synergies inherent in adopting suites of innovations. Thus, such models become discussion tools in cycles of participatory extension. In this way farmers can make informed decisions, weighing up multiple objectives, when moving on a pathway towards a more ecologically intensive farm configuration.

Conclusions

We have shown that there are three main strategies common among farmers in these study sites. These three strategies can be linked to the four management intensification pathways using the narratives created through the typical Q sorts of the three factors. We also showed, by the strength of their agreement or disagreement with different statements, that farmers following different strategies would be likely to adopt certain interventions in a step by step fashion on a trajectory towards more intensive farming configurations. We can draw the following conclusions about these three strategies.

"Autonomous Seed Saving Peasants"

- would be receptive to low cost innovations that involve a knowledge transfer
- would adopt innovations that need to be bought (e.g., PICS bags) at later stages when their finances allow this

"Aspirant Modern Farmers"

- desire to use hybrid seeds and fertilizers
- need effective extension to stimulate effective composting, residue management and legume diversification

"Entrepreneurial Business(wo)men"

- need accurate market related information and access to suppliers of new technologies like mechanization
- can aid in dissemination and demonstration of innovations

That a lack of relation to farm structural features could not be statistically linked to each factor indicates that these features are possibly independent of farmer strategy. Our findings provide insights in development pathways that can be further refined through iterative participatory research and extension. Further, this work supports policy makers in allocating efficient access to inputs through subsidies that will be received and acted on by specific groups of farmers.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10745-023-00413-0.

Acknowledgements The research was funded by the United States Agency for International Development (USAID) (AID-BFS-G-11-00002) as part of the US Government's 'Feed the Future' Initiative. The contents are the responsibility of the producing organizations and do not necessarily reflect the opinion of USAID or the U.S. Government. We would like to thank the following people from the International Institute for Tropical Agriculture (IITA); Dr. Mateete Bekunda, Dr. Irmgard Hoeschle-Zeledon and Dr. Regis Chikowo, from the AfricaRISING project, and Isaac and Emanuel Jambo and all their support staff at the research station in Chitedze, for assisting in logistical arrangements during fieldwork at the Africa RISING sites. We thank Grace Gangu for her tireless reading of statements, and finally we would like to thank all the farmers from Dedza and Ntcheu in Central Malawi who took part in this study. The authors declared that they have no conflict of interest.

Authors' Contributions All authors contributed to defining the research question, the use of the methodology and the creation & refinement of the Q concourse of statements. C.J.T. carried out the fieldwork in Malawi, analysed the data and wrote the draft version of the manuscript. All co-authors contributed to further writing and editing and reviewing of the manuscript.

Funding The research was funded by the United States Agency for International Development (USAID) (AID-BFS-G-11-00002) as part of the US Government's 'Feed the Future' Initiative.

Availability of Data and Materials Dataset is anonymised and available from corresponding author.

Declarations

Ethical Approval The Social Sciences Ethical Committee of Wageningen University granted ethical approval and waived the need for informed consent for this study. Oral consent to participate in this study was obtained from the selected farmers and this study was carried out following all the relevant guidelines and regulations.

Competing Interests None of the authors have any competing interests.

References

Ackoff, R. L. (1990). Redesigning the Future. *Systems Practice, 3*(6), 521–524. https://doi.org/10.1007/BF01059636

Alvarez, S., Timler, C. J., Michalscheck, M., Paas, W., Descheemaeker, K., Tittonell, P. A., Andersson, J. A., & Groot, J. C. J. (2018). Capturing farm diversity with hypothesis-based typologies: An innovative methodological framework for farming system typology development. *PloS One, 13*(5). https://doi.org/10.1371/journal.pone.0194757

Fisher, M., & Snapp, S. (2014). Smallholder farmers' perceptions of drought risk and adoption of modern maize in southern Malawi. *Experimental Agriculture, 50*(4), 533–548. https://doi.org/10.1017/S0014479714000027

Forrester, J., Cook, B., Bracken, L., Cinderby, S., & Donaldson, A. (2015). Combining participatory mapping with Q-methodology to map stakeholder perceptions of complex environmental problems. *Applied Geography, 56*, 199–208. https://doi.org/10.1016/j.apgeog.2014.11.019

Holden, S., & Lunduka, R. (2012). Do fertilizer subsidies crowd out organic manures? *The Case of Malawi. Agricultural Economics, 43*(3), 303–314. https://doi.org/10.1111/j.1574-0862.2012.00584.x

Kamara, A., Conteh, A., Rhodes, E. R., & Cooke, R. A. (2019). The relevance of smallholder farming to African agricultural growth and development. *African Journal of Food, Agriculture, Nutrition and Development*, *19*(1), 14043–14065. https://www.ajol.info/index.php/ajfand/article/view/185577

Malia, C., & Bennett, M. I. (2011). What influences patients' decisions on artificial hydration at the end of life? A Q-methodology study. *Journal of Pain and Symptom Management, 42*(2), 192–201. https://doi.org/10.1016/j.jpainsymman.2010.11.022

Mellon Bedi, S., Kornher, L., von Braun, J., & Kotu, B. H. (2022). Stimulating innovations for sustainable agricultural practices among smallholder farmers: Persistence of intervention matters. *The Journal of Development Studies, 58*(9), 1651–1667. https://doi.org/10.1080/00220388.2022.2043283

Mungai, L. M., Snapp, S., Messina, J. P., Chikowo, R., Smith, A., Anders, E., Richardson, R. B., & Li, G. (2016). Smallholder farms and the potential for sustainable intensification. *Frontiers in Plant Science, 7*, 1720. https://doi.org/10.3389/fpls.2016.01720

Nordhagen, S., Pascual, U., & Drucker, A. G. (2017). Feeding the household, growing the business, or just showing off? Farmers' motivations for crop diversity choices in Papua New Guinea. *Ecological Economics, 137*, 99–109. https://doi.org/10.1016/j.ecolecon.2017.02.025

Peter, B. G., Messina, J. P., Frake, A. N., & Snapp, S. S. (2018). Scaling agricultural innovations: Pigeonpea in Malawi. *The Professional Geographer, 70*(2), 239–250. https://doi.org/10.1080/00330124.2017.1347798

Potts, D. (2006). Rural mobility as a response to land shortages: The case of Malawi. *Population, Space and Place, 12*(4), 291–311. https://doi.org/10.1002/psp.416

Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability, 9*(1), 5–24. https://doi.org/10.3763/ijas.2010.0583

R Core Team. (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Ricker-Gilbert, J., Jumbe, C., & Chamberlin, J. (2014). How does population density influence agricultural intensification and productivity? Evidence from Malawi. *Food Policy, 48*, 114–128. https://doi.org/10.1016/j.foodpol.2014.02.006

Ricker-Gilbert, J., & Jayne, T. S. (2017). Estimating the enduring effects of fertiliser subsidies on commercial fertiliser demand and maize production: Panel data evidence from Malawi. *Journal of Agricultural Economics, 68*(1), 70–97. https://doi.org/10.1111/1477-9552.12161

Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., Wetterstrand, H., DeClerck, F., Shah, M., Steduto, P., de Fraiture, C., Hatibu, N., Unver, O., Bird, J., Sibanda, L., & Smith, J. (2017). Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio, 46*(1), 4–17. https://doi.org/10.1007/s13280-016-0793-6

Rodriguez-Piñeros, S., Focht, W., Lewis, D. K., & Montgomery, D. (2012). Incorporating values into community-scale sustainable forest management plans: An application of Q methodology. *Small-Scale Forestry, 11*(2), 167–183. https://doi.org/10.1007/s11842-011-9182-y

Samberg, L. H., Gerber, J. S., Ramankutty, N., Herrero, M., & West, P. C. (2016). Subnational distribution of average farm size and smallholder contributions to global food production. *Environmental Research Letters, 11*(12), 124010. https://doi.org/10.1088/1748-9326/11/12/124010

Sartas, M., Schut, M., Proietti, C., Thiele, G., & Leeuwis, C. (2020). Scaling Readiness: Science and practice of an approach to enhance impact of research for development. *Agricultural Systems, 183*, 102874. https://doi.org/10.1016/j.agsy.2020.102874

Snapp, S. S., Grabowski, P., Chikowo, R., Smith, A., Anders, E., Sirrine, D., Chimonyo, V., & Bekunda, M. (2018). Maize yield and profitability tradeoffs with social, human and environmental performance: Is sustainable intensification feasible? *Agricultural Systems, 162*, 77–88. https://doi.org/10.1016/j.agsy.2018.01.012

Stephenson, W. (1935). Correlating persons instead of tests. *Journal of Personality, 4*(1), 17–24.

Tittonell, P., Muriuki, A., Klapwijk, C. J., Shepherd, K. D., Coe, R., & Vanlauwe, B. (2013). Soil heterogeneity and soil fertility gradients in smallholder farms of the East African highlands. *Soil Science Society of America Journal, 77*(2), 525–538. https://doi.org/10.2136/sssaj2012.0250

Van der Ploeg, J. D. (2013). *Peasants and the art of farming: A Chayanovian manifesto (No. 2)*. Fernwood Publishing.

Van der Ploeg, J. D., & Ventura, F. (2014). Heterogeneity reconsidered. *Current Opinion in Environmental Sustainability, 8*, 23–28. https://doi.org/10.1016/j.cosust.2014.07.001

Valbuena, D., Groot, J. C., Mukalama, J., Gérard, B., & Tittonell, P. (2015). Improving rural livelihoods as a "moving target": Trajectories of change in smallholder farming systems of Western Kenya. *Regional Environmental Change, 15*(7), 1395–1407. https://doi.org/10.1007/s10113-014-0702-0

Walder, P., & Kantelhardt, J. (2018). The Environmental Behaviour of Farmers-Capturing the Diversity of Perspectives with a Q Methodological Approach. *Ecological Economics, 143*, 55–63. https://doi.org/10.1016/j.ecolecon.2017.06.018

Watts, S., & Stenner, P. (2005). Doing Q methodology: Theory, method and interpretation. *Qualitative Research in Psychology, 2*(1), 67–91. https://doi.org/10.1191/1478088705qp022oa

Zabala, A. (2014). qmethod: A Package to Explore Human Perspectives Using Q Methodology. *The R Journal*, *6*(2):163–173. Available from: https://journal.r-project.org/archive/2014-2/zabala.pdf

Zabala, A., Pascual, U., & García-Barrios, L. (2017). Payments for pioneers? Revisiting the role of external rewards for sustainable innovation under heterogeneous motivations. *Ecological Economics, 135*, 234–245. https://doi.org/10.1016/j.ecolecon.2017.01.011