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Diversity amongst farm households and achievements from multi-stakeholder innovation platform approach: lessons from Balaka Malawi

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Abstract

Background: Understanding diversity of smallholder farm households is of critical importance for the success of development interventions. Farming households often will devise livelihood strategies that provide the best guarantee for survival and based on their socioeconomic vulnerability. This study examines how achievements from the Integrated Agricultural Research for Development (IAR4D) approach through participation in innovation platform activities accrue to smallholder farming households of diverse socioeconomic status. The study is based on a representative sample of smallholder farmers from Balaka innovation platform found in Balaka district of Malawi. Balaka innovation platform was formed in 2009 with the aim of addressing key farmer problems of low crop productivity, lack of input and output markets, limited access to agricultural credit, low incomes and poverty in general. Through multi-stakeholder dialogue, the platform proposed activities meant to improve livelihoods of participants. Some of the activities include conservation agriculture adoption, crop diversification, improved communication through the platform, linking farmers to microfinance institutions and markets, collective market participation, joining farmer groups organised by the platform and various other activities. The main aim was to improve crop productivity, household incomes and food security.

Results: A multivariate study that combines principal component analysis for essential data reduction and cluster analysis to classify typical farm households based on their socioeconomic characteristics and reported achievements from innovation platform activities was used. It is evident from the results that achievements from innovation platform activities are not uniform across farmer groups of different socioeconomic status.

Conclusions: The upshots call for segregated approaches in promoting adoption of various livelihood improving activities, technologies and approaches through the innovation platform approach in smallholder farming areas such as the ones in Balaka, Malawi. Tactics selected by development partners to fight against smallholder farmer problems of low productivity low incomes and food insecurity should conform to farmer socioeconomic vulnerability for greater success.

Keywords: Innovation platform successes, Smallholder farming households, Heterogeneity, Multivariate analysis, IAR4D

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Background

In this paper, we set out to examine how achievements from Integrated Agricultural Research for Development (IAR4D) accrue to smallholder farming households of diverse socioeconomic status using a case of Balaka innovation platform (IP)[1] in southern province of Malawi.

The failure of past development interventions aimed at alleviating poverty and improving household food security in sub-Sahara Africa (SSA) can be blamed on the way they have been effected [1]. Most of these agricultural development methods are characterised by sector fragmentation which reduces their effectiveness in promoting agricultural development amongst smallholder farmers [2]. Moreover, implementation of these interventions has always taken linear and non-participatory Agricultural Research and Development Approaches (ARD) of technology transfer [3, 4]. This has promoted researchers to introduce an Integrated Agricultural Research for Development (IAR4D) model as an alternative agricultural development approach. The IAR4D approach uses innovation platforms (IPs) to surround agricultural research and development organisations in a network to embark on multi-disciplinary and participatory research [5]. The IAR4D approach has been proven to have significant impacts on livelihoods [1, 6, 7]. This paper seeks to investigate how achievements from IAR4D (through participation in IP activities) accrue to smallholder farming households of diverse socioeconomic status. The study argues that, unless IP interventions pay attention to salient heterogeneities in smallholder farming households, the approach might have less than anticipated impacts on overall household prosperity. This study is necessary given that failure to recognise salient heterogeneities in smallholder farming households has been linked to projects yielding lower-than-expected impacts in SSA [8, 9].

In the next subsection, we give a brief background on Balaka IP from which we collected data analysed in this paper.

Background: Balaka multi-stakeholder innovation platform (IP)

Balaka IP was formed in 2009 with the aim of addressing farmer problems. An IP comprises of a group of individuals with different backgrounds and interest: farmers, traders, processors, researchers, government officials, etc. The members come together to diagnose problems, identify opportunities and find ways to achieve their goals. They may design and implement activities as a platform, or coordinate activities by individual members. The Balaka IP was initiated by the International Centre for Tropical Agriculture (CIAT) in 2009. As a research organisation, CIAT identified the broad focus area of the IP. Initially, it identified stakeholders, brought them together and convened meetings. Day-to-day facilitation of the platform was done through the government extension agents. The main problems which were meant to be addressed by the platform in Balaka include low productivity, lack of input and output markets, low incomes and poverty in general. Through multi-stakeholder dialogue, the platform proposed activities meant to improve livelihoods of participants. Some of the activities include conservation agriculture adoption, crop diversification, improved communication through the platform, linking farmers to microfinance institutions, collective market participation, joining farmer groups organised by the platform and various other activities. The IP was then promoting the aforementioned practices and activities. For instance, the IP could facilitate training of farmers on conservation agriculture and diversified farming, inviting local financial and marketing institutions to join the platform with the aim of improving avenues leading to improved financial and market access. In terms of membership composition at survey date, Balaka IP was composed of a number of players including more than 1700 smallholder farmers, CIAT, District Agriculture Development Office (DADO), Department of Agricultural Research Services (DARS), Agricultural Commodity Exchange for Africa (ACE), National Smallholder Farmer Association of Malawi (NASFAM), Agora Limited, Agricultural Development and Marketing Corporation (ADMARC), Monsanto Malawi and several other members [10]. The main aim was to improve household income and food security. Results were meant to be achieved through the strength of the platform. The platform is considered powerful as it leads to better informed decisions, it contributes to capacity development, it makes innovative research possible, and more importantly it can enhance impact. It therefore means farmers can improve their agricultural productivity and profitability and improve how they manage natural resources. More importantly, farmers can increase their income and reduce poverty.

Diversity of households and achievements from development interventions

In this section, the literature on household diversity in terms of socioeconomic status and how it relates to uptake of development interventions and achievements is reviewed.

[1] An innovation platform (IP) is defined as a physical or virtual forum established to facilitate interactions, and learning amongst stakeholders selected from a commodity chain leading to participatory diagnosis of problems; joint exploration of opportunities and investigation of solutions leading to the promotion of agricultural innovations along a targeted commodity chain [5].

Diversity amongst smallholder farming households is mainly grounded on inequalities in resource endowments (capital, land and labour) and access to institutions and markets [11, 12]. Well-resourced households are more likely to meet the requirements needed to adopt development interventions such as technologies when compared to their counterparts (the less resourced). However, households with similar resource endowments and opportunities do not always select the same portfolio of activities [12]. According to Van der Ploeg [13], differences in activity choices by smallholder farming households are influenced by subjective elements such as enterprise styles [13]. This means that a broad range of additional factors including lifestyle, social hierarchy and tradition act together to shape the smallholder farmer's objective function. Differences in goals relating to income, consumption and other livelihood options from one household to the other within communities express diversity amongst seemingly homogenous household types. A combination of farm and non-farm activities is one major source of diversity amongst smallholder farming households.

In addition, differences in social structure are also common in smallholder farming communities. For instance, differences in wealth and power are usually considered as a complicating factor for collective action [14]. Village societies are usually diverse as they may be composed of several agents that largely differ in terms of social class, origin (old vs recent migrants) and ethnicity [12]. This heterogeneity may have positive effects on possibilities of mutual exchange, but it could also undermine social organisation in communities due to conflicts.

Understanding diversity (sources of diversity and consequences) of smallholder farm households is of critical importance for the success of development interventions [12]. Farming households often will devise farming systems and livelihood strategies that provide the best guarantee for survival and based on their socioeconomic vulnerability (as indicated by their socioeconomic position) [15, 16]. This means that farmers will opt for practices (technologies and methods) that permit flexibility in resource allocation and an activity mix that can be adapted to local situations in order to safeguard sustainable livelihoods. Relating to Balaka IP which promoted adoption of a number of innovative practices meant to improve agricultural livelihoods, diversity in farming households could impair adoption of practices and hence achievements of households from such practices. This is plausible, since adoption of innovations is often constrained by limited access to resources and uncertainty regarding the expected returns [12, 17]. Where markets fail, differences in innovative practices adoption such as those promoted in Balaka IP (conservation agriculture adoption, improved crop varieties adoption and collective marketing) are strongly associated with household socioeconomic status (for instance, asset holding and educational skills). According to Ruben and Pender [12], poor farmers tend to select strategies that reduce income vulnerability. They chose technologies and activities that involve low sunk costs and permit high flexibility in resource allocation. As stated by Davies [18], their preference for adaptive livelihoods gives priority to stable returns to labour and land whilst guaranteeing low but stable access to food.

Against this background, this study intends to ascertain farm types in Balaka IP in terms of socioeconomic characteristics and find out how they relate to achievements from interventions promoted through the Balaka IP since 2009.

Methods

This section covers the steps taken in gathering and analysing data. Specifically covered in this section are study site description, sampling and data collection methods, data analysis approach taken and definitions plus descriptive statistics of variables used in the analysis.

Study site

The study was done in Balaka, one of the 13 districts found in the southern region of Malawi. Balaka is mostly in the rain shadow area of Malawi, and the district receives an average rainfall of about 800 mm. The minimum level of rainfall registered is 700 mm, and the maximum is 1100 mm. The minimum and maximum temperatures are 14 and 32 °C, respectively. Maize is the main food crop grown, often in a monoculture but sometimes intercropped with legumes such as cowpeas, pigeon pea and groundnuts. Tobacco, cotton, cassava and many other horticultural crops are also grown. Figure 1 shows the location of Balaka district on the Malawian map.

Data collection and sampling

Cross-sectional data gathered from a household survey conducted using a questionnaire with semi-structured and structured questions are used in this study. The survey gathered data from Balaka IP in Malawi in 2014. In Balaka District, there are about 532 villages with 91 Group village Headmen. For the purpose of this study, all the names of villages in the district were gathered and 5 randomly selected for data collection. The list of households in each of the five villages was obtained, and a sample of 120 households was randomly selected. The sample size in each of the 5 districts was proportional to village size. After data entry and cleaning, a few households were dropped for incomplete data to remain with 116 households.

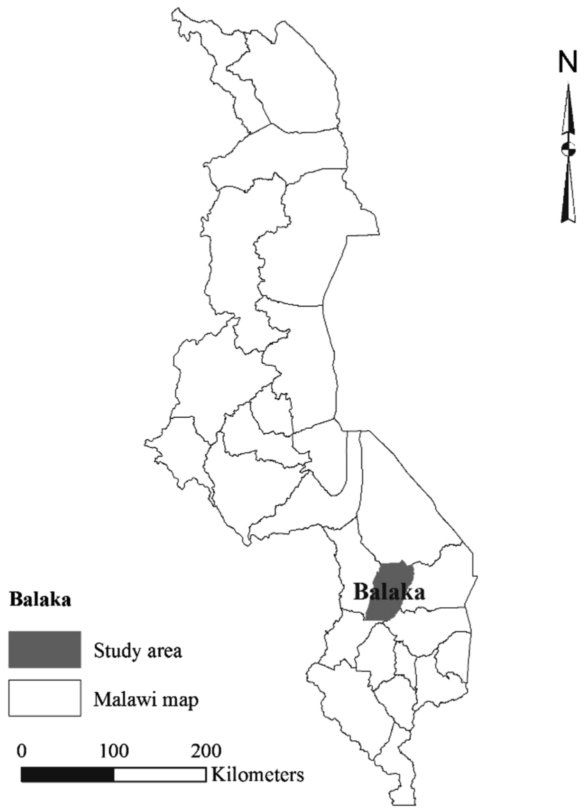

Fig. 1 Map of Malawi showing the location of Balaka district

The survey collected information on household composition and characteristics, cereal and legume crop production, household market participation, access to infrastructure, household incomes, ownership of land and non-land assets, crop diversification (number of crops grown), group membership, conservation agriculture adoption and practice (i.e. is farmer encompassing at least one of the following: minimal soil disturbance, rotations or permanent soil cover as principles of conservation agriculture [19, 20] in his/her farming activities), livestock ownership and access to agricultural inputs on credit, achievements made by households from participating in IP activities since its formation in 2009 and many other socioeconomic variables.

Data analysis approach

This study relies on multivariate analysis to examine household-level data from smallholder farmers in Balaka IP to construct farm household typologies. The multivariate techniques employed in the empirical analysis are of the type used in Nainggolan et al. [21] and other related studies [22, 23]. Firstly, a principal components analysis (PCA) is conducted, a technique which is necessary for data reduction (i.e. to summarise the data sets into smaller and non-correlated dimensions or components) [24]. After that, the study employed a two-stage cluster analysis (CA) technique to characterise the smallholder farmers in the district. As noted in earlier studies, summarising the data through PCA is an important step before undertaking the CA to the data set [22].

Prior to proceeding with the PCA approach, the Bartlett's test [25] and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy were performed to evaluate the appropriateness of the variables to be used as inputs to the PCA approach [26]. The Bartlett's test of sphericity checks the null supposition that the inter-correlation matrix came from a population in which the variables to be used in the PCA are all non-collinear (i.e. an identity matrix [26]). The results from this test using the survey data revealed a significant test ($\chi^2 = 1017.02$; p value $= 0.000$; $df = 435$) suggesting that the variables are uncorrelated hence suitable for a PCA. On the other hand, the KMO test compares the correlations and the partial correlations between the variables with a small KMO suggestive of highly correlated data. Using the Kaiser [27] characterisation, the KMO values revealed that the KMO statistic obtained of 0.553 is in the lower threshold and suggestive of less correlated data. The result supports the appropriateness of the data for the multivariate analysis procedures.

The PCA approach followed the Kaiser criterion of retaining all the components with eigenvalues greater than one (Fig. 2). Also, to simplify the interpretability of the PCA results the components were rotated using the Kaiser's normalisation applicable when the number of variables does not exceed 30 [26], which is the case with the analysed data. This approach has also been applied in recent and related studies [21]. The resulting PCA components are then used as inputs to the CA to typify the different clusters of smallholder farmers in the data set. To better comprehend the farm household typologies of the smallholder farmers in Balaka IP, the study employed a commonly used hierarchical clustering technique called the Ward's procedure to define the number of groups G_i [28]. The study then employed a non-hierarchical, apportioning procedure to refine the created G_i groups [29]. The Ward's clustering criterion combines all the objects that result in an increase in overall within-cluster variation to the smallest degree [30]. Since there is no single procedure applicable to select the minimum number of clusters, the study follows the approaches adopted in Köbrich, Rehman and Khan [23] and requested a total of six clusters from the CA. To ensure that the analysis generates the optimal number of clusters, the study also utilised a dendrogram created from Ward's approach together with an expert knowledge of the study area (Fig. 3). The dendrogram is a pictorial depiction of the

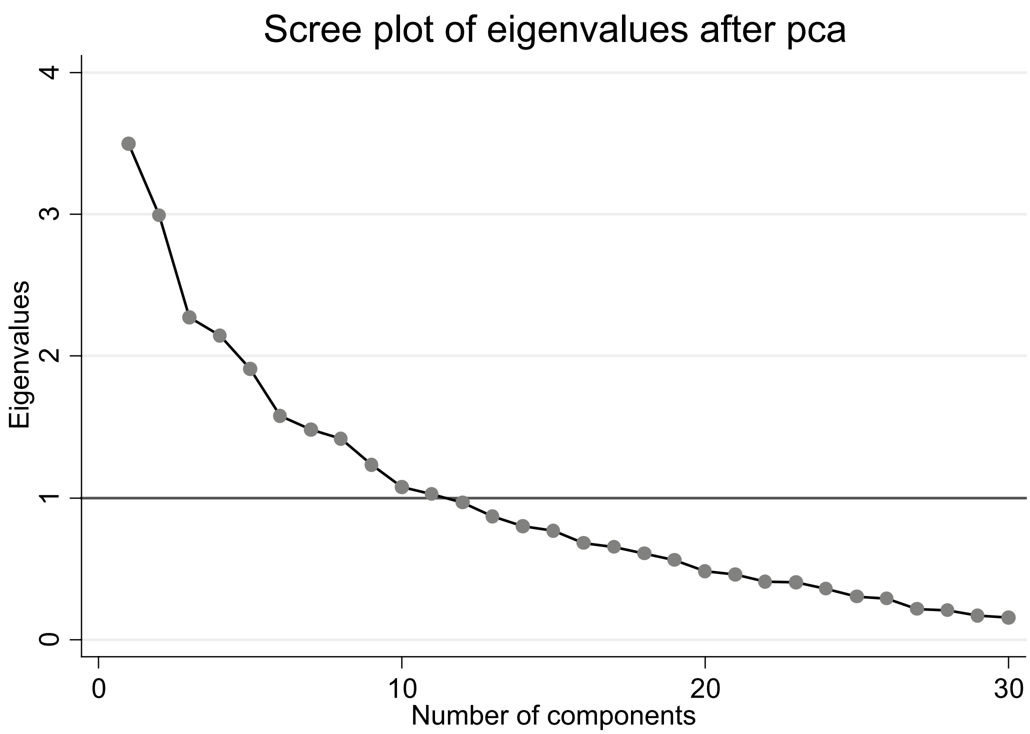

Fig. 2 Scree plot of eigen values from principal component analysis of 30 variables from the study sample of Balaka innovation platform members (smallholder farmers). Components above the ($y = 1$) were retained for further analysis (cluster analysis)

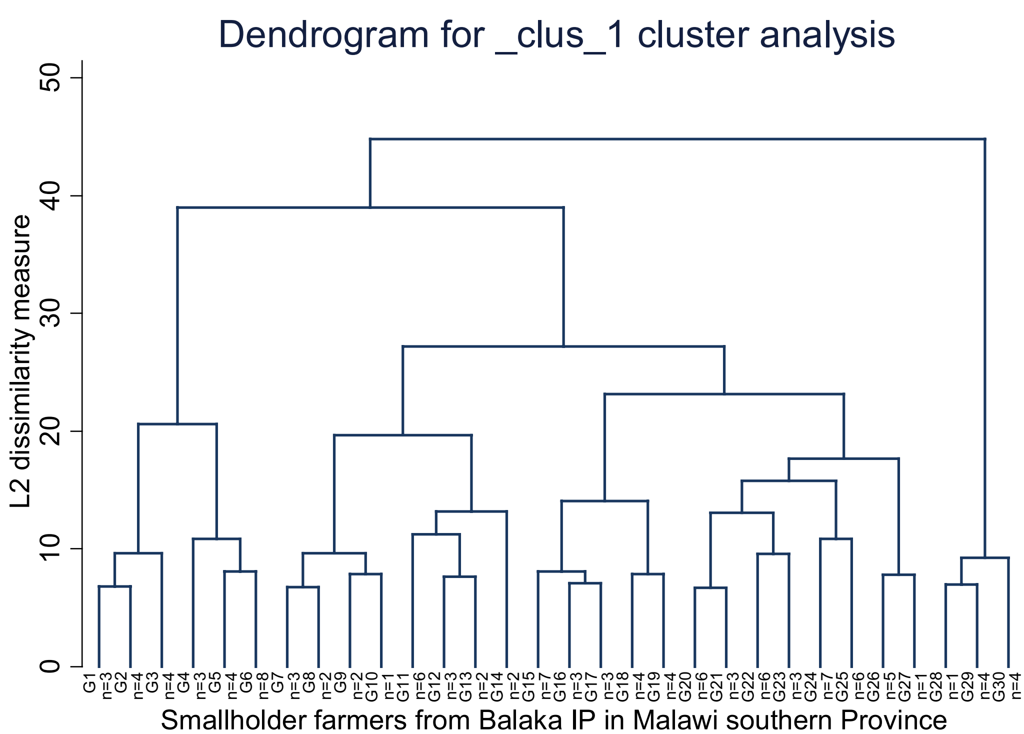

Fig. 3 Dendrogram resulting from Ward's method of cluster analysis using data from Malawi district in Malawi. Note that for brevity we have limited our view to the top 30 branches of the dendrogram with cutnumber (30). These branches are labelled *G1–G30* by default with the respective sample sizes shown beside

hierarchy of the nested cluster solutions. Additionally, the study conducted a one-way analysis of variance (ANOVA) to identify the differences in variability between the generated clusters [26]. This approach allows the researchers to identify specific variables that contribute the biggest differences between the clusters. Researchers conducted all the analysis in STATA version 13.0 using the relevant cluster commands [31].

Results and discussion

In this section, we present variable definitions, descriptive statistics of our variables including results from our principal components analysis (PCA) and cluster analysis. Presentation of results is combined with the discussions.

Variable definitions and descriptive statistics

Household characteristics of farmers from Balaka IP are shown in Table 1. In Table 1, the study reports variable definitions, variable means and standard deviations.

Household characteristics

The demography of the family plays a significant role in household's livelihood activities. This study compiled various demographic characteristics, including gender, age, marital status, education level of the household head and main occupation of the household head (Table 1).

Gender determines differentiation in participation in different household activities which makes it an important factor in agricultural production [32]. About 29.3% of the sampled households are female headed. Age of the household is an important factor of household livelihood activities as it proxies experience and risk perception [22]. Mean age of the household head is 47.28 years. The majority of the households in the sample are married (69.0%) which is a sign of stable society. In addition, most of the household heads had attained at least primary education (96.6%) at the time of the survey. Education is important in livelihood activities of the household as it improves labour skills. Moreover, more educated farmers are able to make better decisions and understand extension messages better than uneducated farmers [32, 33]. Most of the farmers (85.3%) reported farming as their main livelihood activity. The main occupation of the household head is important determinant of farming operations. This is because rural farm households pursue a number of livelihood activities both on- and off-farm and this can determine commitment and investments in agriculture [34].

Access to land is crucial for smooth operations of the farm. Average land size is 1.69 hectares (Table 1). Land scarcity is a pressing issue in Malawi in general, as population continues to increase [35]. This calls for adoption of sustainable intensification practices in farming in order to accomplish household food security demands. Access to labour on the farm is another important factor that can influence adoption of innovation decisions on the farm. Some practices (technology and methods) require more labour as opposed to others [36]. Therefore, households with access to more labour are more likely to realise better achievements from farming that their counterparts ceteris paribus. Mean household size is five people, and mean number of active labourers per household in the sample is three people.

Access to financial capital provides the farming household with the necessary means to finance their farming operations and purchasing of inputs such as seed and fertilizer. The proportion of smallholder farmers in the studied sample who reported to have access to credit as at survey date was 67.2% (Table 1). The rate covers access through both formal and informal means (i.e. getting credit from friends, relatives, IP members, or other small village credit groups). Smallholder farmers access to credit from formal lending institutions is severely limited, as lending institutions in Malawi often require collateral and impose conditions beyond the reach of most smallholder farmers [35].

Access to agriculture extension is an important source of information for farming communities. Agricultural extension officers link farmers with research. About 75% of farmers studied had access to extension services. Membership to community groups was high (62.9%) in the sample. Farmers are expected to get encouragement, inspiration and motivation from other farmers when they work in groups, and such motivation improves their livelihood [32]. In addition, from trainings farmers get knowledge of new and proven innovative practices in farming which helps them in improving their livelihood. In the study sample, access to training services from research organisations and or NGOs is at 73.3% (Table 1).

Household's asset wealth is an important determinant of livelihood activities. Rich and poor households have different capacities to adopt certain innovative practices on the farm, and hence they need to be considered differently. In this study, two categories of asset wealth (low and high wealth) obtained from principal component analysis of household assets [37] are included. Low wealth is a dummy variable indicating the poorly resourced, whilst high wealth indicates the better resourced. In the study sample, 23.3% of farmers are in the low-wealth category, whilst 22.4% are in the high-wealth category.

Achievements and benefits from IP activities

Households were asked a number of questions on the achievements they can attribute to participation in IP activities in Balaka. Most of the questions were yes/no questions indicating whether or not they think they

Table 1 Descriptive statistics for the 30 variables used in the analysis of Balaka IP Malawi

Variables	Definition of the variables	Mean	SD
Household characteristics			
Household head is female	=1 if household head is female; 0 otherwise	0.293	0.457
Age of household head	Age of the household head	49.277	15.716
Education attained at least primary	=1 if household head have at least primary education; 0 otherwise	0.966	0.183
Married	=1 if household head is married; 0 otherwise	0.690	0.465
Main occupation is farming	=1 if the farmer's main livelihood is farming; 0 otherwise	0.853	0.355
Land size	Land size in hectares (ha)	1.694	1.522
Household size	Household size	5.061	2.079
Labour	Labour fit to work in the fields	3.035	1.487
Farming experience	Farming experience	19.812	12.191
Credit access	=1 if household have access to agricultural credit; 0 otherwise	0.672	0.471
Extension access	=1 If household have access to agricultural extension; 0 otherwise	0.750	0.435
Group membership	=1 if household is a member of any community group through the IP or any other means; 0 otherwise	0.629	0.485
Received farmer training services	=1 if the household have access to training activities within the area, i.e. on crop and or livestock production and marketing; 0 otherwise	0.733	0.444
Low-wealth category	=1 if household is in the low-wealth category; 0 otherwise	0.233	0.424
High-wealth category	=1 if farmer is in the high-wealth category; 0 otherwise	0.224	0.419
Achievements and benefits from IP activities			
Improved market information	=1 if farmer Benefited through improve market information access; 0 otherwise	0.414	0.495
Improved market access	=1 if farmer benefited through improved market access; 0 otherwise	0.853	0.355
Improved income	=1 if farmer benefited through increased household income; 0 otherwise	0.828	0.379
Improved conservation agriculture adoption	=1 if improved conservation agriculture adoption (i.e. more land area or crops under conservation agriculture) was a benefit of IP participation; 0 otherwise	0.897	0.306
Improved soil fertility	=1 if farmer benefit through improved soil fertility; 0 otherwise	0.750	0.435
Improved crop yield	=1 if farmer benefited through improvement in crop yields; 0 otherwise	0.164	0.372
IP_savings eased credit access	=1 if farmer benefited from improved credit access through Improved savings from IP activities; 0 otherwise	0.319	0.468
Negotiation with banks eased credit access	=1 if farmer benefited from improved ease of credit access through negotiations done with local banks from IP activities; 0 otherwise	0.060	0.239
Improved trust eased credit	=1 if farmer benefited from ease of access to credit made possible by improved trust amongst villagers through IP activities; 0 otherwise	0.371	0.485
Number of markets increased	=1 if farmer number of produce market outlets have increased through IP activities; 0 otherwise	0.759	0.430
Food produced 2012/2013 season was enough	=1 if food produced in 2013/2014 season was enough to feed the family; 0 otherwise	0.819	0.387
Food produced 2013/2014 season was enough	=1 if food produced in 2013/2014 season was enough to feed the family; 0 otherwise	0.759	0.430
Improved overall food security	=1 if overall household food security improved from IP activities	0.828	0.379
Farmers built a house	=1 if farmer built a new house and income from IP activities contributed immensely; 0 otherwise	0.560	0.498
Farmers was able to send children to school	=1 if farmer was able to send children to school because of benefits from IP activities; 0 otherwise	0.836	0.372

Data were collected from selected smallholder farmers in Balaka District of Southern Malawi in 2014

achieved or benefited on a particular aspect from participating in the IP activities. Summary statistics from the responses recorded are shown in the bottom part of Table 1. A number of social and economic achievements were reported by farmers who participated in Balaka IP activities from its inception in 2009.

Chief amongst the targets of the IP in Balaka was to link smallholder farmers to input and output markets [1]. Linking farmers to markets was made possible by bringing both government and private marketing institutions in the platform. The Agricultural Development and Marketing Corporation (ADMARC) (government institution), the National Smallholder Farmer Association of Malawi (NASFAM) (independent institution), fertiliser and seed houses are some of the key marketing stakeholders present in the IP. Such institutions improved access to input and output markets for the farmers in Balaka IP. From the study, 41.4% of the farmers reported improved market information, 85.3% reported improved market access, and 75.9% reported a general increase in the number of input and output markets (Table 1).

The IP project work in Balaka had another aim of ensuring efficient water and nutrient use in cereal-legume systems, using conservation agriculture. Promotion of conservation agriculture was therefore at the centre of project implementation activities [4]. Conservation agriculture improves soil structure with minimum disturbance of the natural soil ecology [38]. Farmers reported improved adoption of conservation agriculture (89.7%), improved soil fertility due to conservation agriculture adoption (75.0%) and improved crop yields (16.4%). All the achievements/benefits were attributed to participation in IP activities by farmers.

Lack of access to credit was a major problem to be addressed through activities within the Balaka IP. Smallholder farmers in Malawi lack access to financial capital [35] as they fail to meet collateral requirements demanded by formal credit institutions. The IP has been addressing this situation by organising farmers to enable negotiations with banks, promoting local savings amongst farmers themselves, promoting group participation and improving trust amongst IP members to ease credit scarcity-related challenges. In the study sample, 31.9% reported improved savings within the IP to have improved credit access, 37.1% reported improved trust amongst members to have eased credit access within the IP, whilst only 6% reported negotiation with banks through the platform to have improved access to credit (Table 1).

Overall, the efforts of the project were meant to improve agricultural productivity and livelihoods [4]. Improving food security and income was therefore the key target. About 82.8% of the households reported improved income as an achievement from participation in IP activities in Balaka, 81.9 and 75.9% (Table 1) of the households reported that food produced in 2012/2013 and 2013/2014 agricultural seasons, respectively, was enough to feed the family, and 82.8% of the households stated that general food security within the household improved through IP activities in Balaka. Additionally, 83.6% of the households were able to send their children to school and 56.0% were able to build an additional structure within the homestead (e.g. a house). In general, it is evident that based on farmers' responses to questions analysed in this study, a bigger portion of them achieved/benefited greatly from IP activities in Balaka. From multivariate analysis performed, results (shown in the next section) show how achievements differed by socioeconomic status of the farm households.

Results from principal component analysis

In Table 2, we present PCA results. A total of 30 variables presented in Table 1 were included in PCA, of which 11 principal components with Eigen values greater than 1 were retained for further analysis (Fig. 2). The variables explain 68.77% of total variance. As shown in Table 2, it was possible to define components according to the variables each component is strongly associated with. Component loadings with scores greater than 0.4 are in bold for easy identification.

Component 1 explains 8.92% of variability and is positively correlated with improved market access, improved household income and improved conservation agriculture adoption. Thus, the component represents farmers who improved conservation agriculture adoption and were linked to new markets which eventually improved their household incomes. Component 2 explains 8.00% of variability and correlates positively with household size, labour and sending children to school. The component is thus for households with large families who were more likely to send their children to school as an achievement from participating in IP activities. The third and fourth components are almost equal in importance, and they explain 6.67 and 6.48%, respectively. Component 3 correlates negatively with female household headship and positively with married household head, whilst component 4 correlates positively with age and farming experience. Thus, component 3 represents married male farmers, whilst component 4 represents the highly experienced farmers.

The fifth and sixth components are almost equal in importance as the third and fourth components. Component 5 explains 6.40% variability in data and correlates positively with overall household food security, and food produced during 2012/2013 and 2013/2014 seasons being enough to cover household cereal needs. Thus, the component represents household food security. On the other hand, component 6 explains 6.19% variability in data and correlates positively with general access to credit and improved access to credit through IP savings. The component, thus, represents credit access.

Component 7 explains 5.72% variability and correlates positively with farming as the main occupation and negatively with high wealth. The component, thus, represents poor full-time farmers. The eighth component correlates positively with land size and negatively with improved soil fertility. It explains 5.52% of variability in data. The component, thus, represents large land sizes with no

Table 2 Distribution of the eleven components extracted from principal components analysis including the factor loadings of the 30 variables and the cumulative proportion of the explained variance plus eigen values

Variable	Components										
	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9	Comp10	Comp11
Household characteristics											
Household head is female	0.0175	−0.0523	*−0.5742*	0.0193	0.0336	0.016	0.0718	−0.0025	−0.0145	0.1265	−0.1083
Age of household head	0.0424	0.014	0.0341	*0.6177*	0.0196	0.0102	0.0834	0.0402	−0.0509	−0.0283	−0.0037
Education attained at least primary	−0.04	−0.0902	0.202	−0.0344	−0.0511	0.0361	−0.0056	−0.0894	−0.0446	0.0043	*0.5846*
Married	0.0397	0.179	*0.4356*	−0.0933	0.0547	−0.136	−0.0174	−0.0102	0.2031	0.0003	0.0718
Main occupation is farming	−0.0934	0.1368	−0.1359	0.1058	−0.1392	−0.0043	*0.5641*	−0.02	0.0172	0.0699	0.1692
Land size	0.0584	0.0224	−0.0249	0.0688	0.1344	−0.0244	0.0411	*0.6367*	0.007	0.0513	0.002
Household size	−0.0527	*0.542*	0.1222	0.023	−0.048	−0.0514	0.0459	−0.0598	0.0517	−0.044	0.0087
Labour	−0.0006	*0.5538*	0.0373	0.1595	−0.0381	−0.0229	−0.1297	−0.0284	−0.0805	−0.0353	−0.0535
Farming experience	0.0126	0.0596	−0.0534	*0.6241*	0.0009	0.0168	−0.0588	0.0409	0.0544	0.0494	0.0023
Credit access	0.0502	0.0496	0.0191	−0.1964	0.0401	*0.5081*	0.008	0.0548	−0.0711	0.2511	0.0948
Extension access	0.0166	0.065	−0.2334	0.0309	0.1286	0.147	−0.1279	−0.269	0.2835	−0.0199	0.0214
Group membership	0.1252	−0.0813	−0.0109	0.0701	−0.0883	−0.0029	−0.0464	−0.0858	0.3819	−0.0034	0.3542
Received farmer training services	0.1087	0.0898	0.0961	−0.0642	0.1196	0.0422	0.1008	−0.2615	0.1307	*0.5064*	−0.2115
Low-wealth category	0.139	−0.0737	0.0088	0.0308	−0.0489	0.2292	0.3455	−0.1202	−0.2657	−0.269	−0.1179
High-wealth category	−0.0256	0.1499	−0.0698	0.0697	−0.0787	0.0663	*−0.5971*	−0.0452	−0.148	0.0731	0.0956
Achievements and benefits from IP activities											
Improved market information	0.269	−0.1151	0.2994	0.0098	−0.2094	0.1483	−0.038	0.1972	−0.2278	0.1318	−0.0124
Improved market access	*0.558*	−0.0301	0.0112	0.019	0.0037	−0.0511	0.0222	−0.0137	−0.0428	−0.0197	0.0339
Improved income	*0.4631*	0.0161	−0.0513	−0.01	0.02	0.0827	−0.1071	0.0808	0.1389	−0.0728	−0.0108
Improved conservation agriculture adoption	*0.5068*	0.0304	−0.0177	0.0637	−0.0112	−0.0632	0.0055	−0.0535	0.0371	0.0494	−0.06
Improved soil fertility	0.1731	0.1012	−0.0776	−0.0057	0.1656	−0.1027	0.1308	*−0.4478*	−0.2695	0.1345	0.1406
Improved crop yield	0.0279	−0.0011	0.0689	−0.0149	−0.0232	−0.0088	0.2012	0.0919	*0.5861*	0.029	−0.0442
IP_savings eased credit access	−0.0509	−0.0317	−0.0172	0.0941	−0.044	*0.6402*	−0.0504	−0.0273	0.0337	−0.1623	0.0397
Negotiation with banks eased credit access	0.0025	0.223	−0.0468	−0.0915	0.0046	−0.1116	0.175	0.2712	−0.2236	0.1403	0.1094
Improved trust eased credit	−0.0513	−0.1105	−0.0866	0.0609	−0.1024	−0.064	−0.0743	0.1037	−0.0517	*0.6476*	0.0916
Number of markets increased	−0.1159	−0.0384	0.3939	0.1709	0.2175	0.2666	0.1364	−0.048	0.0066	0.1846	−0.1391
Food produced 2012/2013 season was enough	−0.06	0.0471	0.0668	0.0231	*0.4937*	0.034	−0.0094	−0.0575	−0.1321	0.0087	−0.0162
Food produced 2013/2014 season was enough	0.0922	−0.073	0.0198	−0.0076	*0.4662*	−0.1585	0.0232	0.0538	−0.1294	−0.1431	0.3058
Improved overall food security	−0.0118	−0.0652	−0.046	0.0072	*0.5444*	0.0384	−0.0755	0.1253	0.129	0.0088	−0.1234
Farmer built a house	−0.0127	0.1301	−0.1833	0.0274	0.108	0.1664	0.0638	0.1072	0.0601	0.0616	*0.4761*
Farmer was able to send children to school	0.1122	*0.4071*	−0.1482	−0.257	0.0398	0.1957	0.0437	0.1807	0.0425	−0.0639	−0.0577
Eigen values	2.677	2.401	2.002	1.944	1.920	1.856	1.716	1.656	1.616	1.446	1.400
Cumulative proportion of explained variance (%)	8.92%	16.93%	23.60%	30.08%	36.48%	42.66%	48.38%	53.91%	59.29%	64.11%	68.77%

Comp component. Factor loadings 0.4 and higher are marked in italic font improvements in soil fertility. Component 9 explains 5.39% variability and correlates positively with improved crop yield. The component, thus, represents households with improved crop yield as their benefit from implementing IP activities.

Components 10 and 11 explain nearly 4.82 and 4.67% of the variance, respectively. The tenth component correlates positively with training received from IP activities and improved credit access as a result of improved trust from the IP approach. Thus, training and interactions with other members within the IP improved trust amongst members which enhanced resource sharing, i.e. credit lending and borrowing. Component 11 correlates positively with attainment of at least primary education and building an additional structure such as house as an achievement from IP activities. The component is, thus, for the educated household heads who were more likely to build an extra structure (a house) as a notable achievement from IP activities.

Results from cluster analysis

In Table 3, characteristics of the six clusters defined by cluster analysis are shown. Specifically, shown in the table are shown the characteristics of selected clusters of farm households in Balaka IP and *p* values of one-way analysis of variance (equality of group means). For a guide in interpretation, the more distinctive a variable value is amongst groups, the lower is its *p* value.

In order to obtain a meaningful classification, the study utilised a dendrogram created from Ward's technique with an expert knowledge of Balaka district (Fig. 3). From the classification and *p* values shown in Table 3, it is clear that various socioeconomic factors such as gender, age, education, land size, household size, labour, farming experience, access to credit, access to extension services, access to farmer training services and wealth distinguish clusters. This is true for all variables representing reported benefits/achievements from innovation platform activities except for improved market information access, improved trust and building an additional structure such as a house, which shows good choice of variables for a multivariate analysis.

Cluster 1: oldest group, experienced, low credit access and limited labour

The first cluster constitutes about 9.5% of the sample (Table 3) and is distinguishably characterised by the oldest members (mean age of 67.55 years), with high level experience (29.31 years on average) but low levels of credit access (27.30%) and low labour (2.55 labourers per household on average). In addition, the cluster achieved comparatively high (as shown by above total sample average rates in recorded responses) in the following: improved market access (100%), improved conservation agriculture adoption (100%), improved soil fertility (91%), increased number of markets (91%), food produced during 2012/2013 and 2013/2014 season being enough to feed the household (82%) and (91%), respectively. Reported improvements in overall food security in the cluster (81.8%) were close to the all clusters' average of 82.8%. On the other hand, the cluster reported poor rates (below total sample averages) in achieving the following: improved crop yields (9.1%), improved savings that eased credit access (9.1%) and being able to send their children to school (9.1%). Experience in farming activities could explain comparatively higher achievements in stated variables. However, lack of credit access and labour could be constraining significant improvement in crop yields and hence subsequent benefits such as improved savings and being able to send children to school using income from farming activities.

Cluster 2: female, single farmers with credit, training and extension access

Cluster 2 constitutes about 12.9% of the sample and is characterised by female farmers (73.3%), with the smallest marriage rates (13.3%) but with access to credit (93.3%), farmer training services (80%) and extension (100%). Additionally, the cluster has comparatively high levels of farming experience (group average of 28.6 years) and relatively poor asset wealth as indicated by high (low) representation in the low (high) wealth groups 73.3% and 13.3%, respectively. In terms of benefits/achievements from IP activities, the group reported above average rates in achievements/benefits such as improved market access (93.3%), improved income (86.7%), improved conservation agriculture adoption (100%), improved soil fertility (100%), improved savings (80%), increased number of markets (93.3%), food produced in 2012/2013 and 2013/2014 seasons being enough to cover household needs 100% and 86.7%, respectively, improved overall household food security (86.7%) and being able to send children to school (86.7%). However, this cluster reported below average rates in improved crop yields (6.7%), eased credit access because of improved trust amongst households through IP interactions (26.7%) and eased access to credit because of negotiations between formal financial institutions in Balaka district and IP members (0%). Significant benefits and achievements recorded in this group could be due to comparably higher level access to credit, training services and extension access. This group seems to be that of single women who benefit from informal credit savings groups initiated through the IP or from already functional women groups present in the district. Promoting women empowerment through self-help groups such as women credit groups such the ones

Table 3 Characteristics of selected clusters of smallholder farmers from Balaka IP southern province of Malawi

	(1) Cluster I	(2) Cluster II	(3) Cluster III	(4) Cluster IV	(5) Cluster V	(6) Cluster VI	(7) All clusters		*p* values
	Means	Means	Means	Means	Means	Means	Means	SD	
Household characteristics									
Household head is female	0.364	0.733	0.476	0.048	0.135	0.222	0.293	0.457	0.0000
Age of household head	67.545	60.867	45.667	57.048	39.806	37.333	49.277	15.716	0.0000
Education attained at least primary	1.000	1.000	0.857	1.000	1.000	1.000	0.966	0.183	0.0159
Married	0.545	0.133	0.619	0.952	0.892	0.667	0.690	0.465	0.0000
Main occupation is farming	0.818	1.000	0.905	0.762	0.811	1.000	0.853	0.355	0.2393
Land size	1.282	1.113	0.952	1.729	2.212	2.544	1.694	1.522	0.0079
Household size	2.545	3.800	5.524	6.524	5.378	4.889	5.061	2.079	0.0000
Labour	1.545	2.267	3.476	4.286	3.000	2.333	3.035	1.487	0.0000
Farming experience	29.309	28.600	19.714	26.762	12.216	9.111	19.812	12.191	0.0000
Credit access	0.273	0.933	0.381	0.952	0.730	0.556	0.672	0.471	0.0000
Extension access	0.545	1.000	0.905	0.905	0.622	0.556	0.750	0.435	0.0017
Group membership	0.727	0.667	0.762	0.762	0.541	0.333	0.629	0.485	0.1373
Received farmer training services	0.727	0.800	0.619	0.952	0.811	0.222	0.733	0.444	0.0006
Low-wealth category	0.273	0.733	0.286	0.048	0.162	0.000	0.233	0.424	0.0000
High-wealth category	0.091	0.133	0.286	0.429	0.216	0.000	0.224	0.419	0.0792
Achievements and benefits from IP activities									
Improved market information	0.455	0.400	0.381	0.429	0.541	0.000	0.414	0.495	0.1117
Improved market access	1.000	0.933	1.000	0.905	0.892	0.000	0.853	0.355	0.0000
Improved income	0.818	0.867	1.000	0.952	0.865	0.000	0.828	0.379	0.0000
Improved conservation agriculture adoption	1.000	1.000	1.000	1.000	0.946	0.000	0.897	0.306	0.0000
Improved soil fertility	0.909	1.000	0.667	0.714	0.784	0.333	0.750	0.435	0.0051
Improved crop yield	0.091	0.067	0.333	0.381	0.054	0.000	0.164	0.372	0.0022
IP_savings eased credit access	0.091	0.800	0.286	0.571	0.135	0.111	0.319	0.468	0.0000
Negotiation with banks eased credit access	0.000	0.000	0.000	0.000	0.135	0.222	0.060	0.239	0.0328
Improved trust eased credit	0.636	0.267	0.190	0.381	0.405	0.444	0.371	0.485	0.1978
Number of markets increased	0.909	0.933	0.381	1.000	0.703	0.889	0.759	0.430	0.0000
Food produced 2012/2013 season was enough	0.818	1.000	0.429	0.905	0.919	0.889	0.819	0.387	0.0000
Food produced 2013/2014 season was enough	0.909	0.867	0.429	0.667	0.919	0.778	0.759	0.430	0.0004
Improved overall food security	0.818	0.867	0.571	0.952	0.892	0.889	0.828	0.379	0.0151
Farmer built a house	0.364	0.733	0.429	0.667	0.541	0.667	0.560	0.498	0.2696
Farmer was able to send children to school	0.091	0.867	0.952	1.000	0.973	0.667	0.836	0.372	0.0000
N (%)	11 (9.48)	15 (12.93)	21 (18.10)	21 (18.10)	37 (31.90)	9 (7.76)	116 (100)		

SD standard deviation. Data were collected from selected smallholder farmers from Balaka IP in southern province, Malawi, *p* value is for one-way ANOVA (equality of group means)

stated in Waller [39] is now a common phenomenon in Malawi. However, the low rates in improved crop yields could be explained by the general lack of access to productive resources in farming associated with women in sub Saharan Africa [36, 39].

Cluster 3: low land sizes

Cluster 3 is distinguishably characterised by low land sizes (0.91 ha on average) and below average proportions in household heads with at least primary education (85.7%). The cluster constitutes 18.1% of the study sample. The cluster reported above average rates in benefits/achievements realised from participating in IP activities such as improved market access (100%), improved income (100%), improved conservation agriculture adoption (100%), improved crop yields (33.3%) and being able to send children to school (95.2%). However, the group reported below average rates in improved soil fertility (66.7%), IP savings (28.6%), increased number of markets (38.1%) and improvement in food security, i.e. food produced during 2012/2013 and 2013/2014 seasons being enough to meet household needs (42.9%) and overall food security (57.1%). Relatively smaller land sizes of 0.91 ha per household observed in this cluster could be encouraging farmers to adopt sustainable intensification practices such as conservation agriculture promoted by the IP. Sustainable intensification improves crop yields and subsequent income from farming activities given the improvement in market access enhanced by the IP and reported in this group. As a result of income improvements realised, households can be able to send their children to school.

Cluster 4: rich, married male farmers with labour and access to credit and training

Cluster 4 constitutes about 18.1% of the study sample and is characterised by the highest representation of married male household heads (95.2%) with the largest household sizes (6.52 members on average) and labourers (4.29 members per household). In addition, the group has access to farmer training services and relatively better asset wealth [as shown by high (low) representation in the high (low)-wealth category 42.9 (4.8) %] when compared to all other clusters. On the other hand, the cluster has above average rates in reported benefits/achievements such as improved market access (90.5%), improved income (95.2%), improved conservation agriculture adoption (100%), improved crop yields (38.1%), eased credit access through IP savings (57.1%), increased number of markets (100%), food produced during 2012/2013 season being enough to meet household needs (90.5%), overall household food security (95.2%) and being able to send children to school (100%). However, the cluster reported below average proportions on responses citing improvements in soil fertility (71.4%) and food produced during 2013/2014 season (66.7%) were reported in this group. A number of factors can explain findings in this cluster. Better access to productive resources associated with male farmers [36], and significance of labour in farm production activities [22] can explain the findings. More so, the importance of financial capital (credit) in purchasing productive inputs [40] and improved social capital (through training services) in improving information essential to farming operations [32] could explain improved conservation agriculture adoption, improved crop productivity and income in this cluster. Subsequently, households are expected to be relatively more food secure given the improvement in crop yields, income and improved access to input and output markets. The below average improvements in soil fertility can be attributed to selective adoption of conservation agriculture practices [41] which may undermine significant soil fertility improvements.

Cluster 5: young, married, medium rich farmers with large land sizes

This cluster constitutes about 32% of the sample and is distinguishably characterised by relatively young farmers (mean age 39.81) who are married (89.2%) with relatively large land sizes (2.21 ha on average), medium rich (21.6% in high-wealth category) and about 73% reporting to have access to credit. On the other hand, the group has above average proportions of household members who benefited in: improved market access (89.2%), improved income (86.5%), conservation agriculture adoption (94.6%), improved soil fertility (78.4%), food produced during the 2012/2013 and 2013/2014 seasons being enough to cover household needs (91.9%) and overall food security improvement (89.2%). In addition, about 13.5% of the members reported that negotiations with banks eased credit access (13.5%) and about 97.3% of the members were able to send their children to school. However, members in this cluster reported less than average improvements in: crop yields (5.4%), improved credit access due to IP savings (13.5%) and increased number of markets (70.3%). This cluster may represent youthful farmers who inherited land and asset wealth from their parents and consider farming as their main livelihood. The group is realising benefits from the IP platform activities like most groups as indicated by considerable rates in adoption of conservation agriculture and improvements in soil fertility and incomes. Distinctively, the group reported improved credit access from formal institutions due to negotiations carried out with banks through the platform which might indicate that young farmers are more likely to approach formal banks to apply for credit unlike older farmers.

Cluster 6: youngest, land size, least experience

Cluster 6 constitutes 7.8% of the sample and is characterised by the youngest group of farmers (mean age 37.33 years) with minimal farming experience (9.11 years), big family sizes (4.89 members on average) and land sizes (2.54 ha on average). The cluster had the least percentage access to training services (22.2%). On the other hand, the group only reported benefits in a few aspects including; increased number of markets (88.9%), eased credit access due to negotiations with banks (22.2%) overall food security and food produced during 2012/2013 season being enough to meet household needs (88.9%) and food produced 2013/2014 being enough to meet household needs (77.8%). However, the group did not report any improvements in conservation agriculture adoption, improved income from farming and improvement in crop yields. The cluster also reported below average rates in eased credit access through IP savings (11.1%) and being able to send their children to school

(66.7%). This cluster could be representing young farmers who have farming as their main occupation but could be involved in other off-farm activities to support their relatively larger family sizes. Generally, older household heads are expected to have larger families [42], which means that farmers in this cluster could be representing son/daughter taking care of siblings and/or own family after parents are deceased. Little farming experience and high household dependency could be a major constraint limiting conservation agriculture adoption and improvement of crop yields.

Conclusions and implications

The main objective of the paper was to investigate how achievements from Integrated Agricultural Research for Development (IAR4D) approach [through participation in innovation platform (IP) activities] accrue to smallholder farming households of diverse socioeconomic status using a case study of Balaka IP in southern province of Malawi. The study relied on a multivariate analysis approach that combines principal component analysis, and cluster analysis to identify six distinctive farm household types within Balaka IP with respect to realisation of benefits/achievements from participation in IP activities, using socioeconomic factors. Data on 30 variables from 116 smallholder farmers participating in Balaka IP activities since 2009 are analysed. Principal component analysis identified 11 components that accounted for nearly 68.77% of variance in the original 30 variables. The identified ten components were used in cluster analysis to characterise Balaka IP farmers. Using expert knowledge of Balaka district and the ward technique, cluster analysis led to the creation of six farm types. It is evident from the results that achievements from IP activities are not uniform across farmers groups of different socioeconomic status. A number of factors such as gender, age, education of household head, land size, household size, labour endowment, farming experience, access to credit, access to extension services, access to farmer training services and wealth distinguish clusters and can be associated with realisation of benefits/achievements from IP activities.

For example, clusters with single women with access to credit (through village savings group), training services and extension were found to realise improvements in conservation agriculture adoption, soil fertility, market access, improved income and food security status. The same with clusters characterised by highly experienced farmers, they realised improvements in conservation agriculture adoption but with less than average improvements in crop yields. Clusters characterised by low land sizes were found to realise improvements in sustainable intensification practices adoption such as conservation agriculture, and also they realised improvements in crop yields and incomes. Moreover, households in such clusters were found to realise improvements in their capability/chances of sending their children to school. On the other extreme, clusters characterised by young farmers with large land sizes realised comparatively less benefits/achievements compared to other clusters, but they were more likely to approach formal banks in applying for credit hence benefiting from negotiations with formal lending institutions done through the IP. However, most clusters benefited almost equally in terms of access to input and output markets.

Statistical testing showed that the discriminating power of most of the variables used in the analysis and of the variables representing achievements/benefits from IP activities is high. This indicates that the farm types constructed can be useful to explore realisation of benefits in the study sample.

In conclusion, innovation platform activities as reported by farmers in this case study of Balaka improve household livelihoods. The IP achieve this through promoting uptake of a number of sustainable farming technologies and methods, improving access to markets, information and credit which in turn improve soil fertility, crop yields and returns from farming amongst other benefits. It is therefore important for development practitioners to embrace the innovation platform approach in implementing activities meant to fight poverty in developing areas such as Balaka. Out and up-scaling innovation platform activities in Malawi can yield significant livelihood benefits to smallholder farmers. However, as benefits accrue in a different fashion to farmers of different socioeconomic status, it calls for segregated approaches in promoting various activities, technologies and approaches through the innovation platform approach in smallholder farming areas. Tactics of fighting problems of low productivity, lack of input and output markets, low incomes and poverty in general through conservation agriculture adoption, improved communication through the platform, linking farmers to microfinance and marketing institutions, collective market participation, joining farmer groups organised by the platform and various other activities should conform to farmer socioeconomic characteristics. No single uniform approach will equally impact on farmer livelihoods in a heterogeneous population. Therefore, promotion of activities should be more focused on specific groups of smallholder farmers such as these farm types defined.

Abbreviations

ACE: Agricultural Commodity Exchange for Africa; ADMARC: Agricultural Development and Marketing Corporation; ARD: Agricultural Research for Development; CA: cluster analysis; CIAT: International Centre for Tropical Agriculture; DADO: District Agriculture Development Office; DARS: Department of Agricultural Research Services; GOM: Government of Malawi; IAR4D:

Integrated Agricultural Research for Development; IP: innovation platform; KMO: Kaiser–Meyer–Olkin; NASFAM: National Smallholder Farmer Association of Malawi; PCA: principal component analysis; SSA: sub-Sahara Africa.

Authors' contributions
CM designed the study, analysed data and drafted the manuscript NM, coordinated the implementation of the study, supervised the design of the research and revised the manuscript. Both authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests.

Availability of supporting data
Data for this study can be obtained from CIAT Dataverse. Repository URL https://dataverse.harvard.edu/dataverse/CIAT.

Consent for publication
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Ethical approval and consent to participate
The study was approved by the International Centre for Tropical Agriculture in collaboration with Malawi Ministry of Agriculture and Food Security. Informed consent was obtained from all the participants. The authors have all the ethical approval and consent to take and participate in research paper writing and submission to any relevant journal from our organisations where we are working and posted.

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