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A comparison of statistical and participatory clustering of smallholder farming systems – A case study in Northern Ghana

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A B S T R A C T

Typologies are often used to understand and capture smallholder farming system heterogeneity, and may be derived using different approaches and methods. This article aims to compare a quantitative, statistical typology based on a survey dataset and multivariate analysis, with a qualitative participatory typology based on informal group sessions and activities with local stakeholders from three communities in Northern Ghana. The statistical typology resulted in six clusters, with farm households categorized on the basis of their structural (resource endowment)- and functional (production objectives/livelihood strategies) characteristics. The participatory typology identified five farm types, based primarily on endowment (farm size, income investment), gender and age-related criteria. While the entire household was adopted as the unit of analysis of the statistical typology, the participatory typology provided a more nuanced differentiation by grouping individual farmers; with possibly several farmer types per household (*e.g.* 'small' and 'female farmers') as well as 'farm-less' individuals as a result. Other sources of dissimilarity which contributed to limited overlap between the typologies included changes that occurred in the communities between the two data collection efforts and inaccuracies in the data. The underlying causes of the latter seemed to mainly relate to socio-cultural issues that distorted information collection in both typologies; including power and status differences between both the researchers and farmers, as well as the farmers themselves. We conclude that although statistical techniques warrant objectivity and reproducibility in the analysis, the complexity of data collection and representation of the local reality might limit their effectiveness in selection of farms, innovation targeting and out-scaling in R4D projects. In addition, while participatory typologies offer a more contextualized representation of heterogeneity, their accuracy can still be compromised by socio-cultural constraints. Therefore, we recommend making effective use of the advantages offered by each approach by applying them in a complementary manner.

1. Introduction

In Sub-Saharan Africa, the primary producers of agricultural outputs are smallholder farmers, who account for 80% of all farms in the region (AGRA, 2014). Smallholders are perceived to share certain characteristics which differentiate them from larger-scale, profit-driven producers. Such characteristics include: limited access to land, financial capital and inputs, high levels of vulnerability and low market participation (Chamberlin, 2007, 2008). However, far from being homogeneous; like farms everywhere, smallholdings are adapted to the conditions of their biophysical, economic, and socio-institutional environments (Ruthenberg, 1971). In this study, a farming system is defined as the complex of resources that are arranged and managed according to the totality of production and consumption decisions taken by a farm household, including the choice of crops, livestock, on-farm and non/off-farm enterprises (Fresco and Westphal, 1988; Köbrich et al., 2003). The process of

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adapting to different macro- and micro-level contexts has resulted in a rich diversity of smallholder farming system configurations at all scales (*i.e.* household, village, region and country) across the African continent (Tittonell et al., 2010; Giller, 2013). This diversity is made manifest spatially (*e.g.* based on resource endowment), temporally (by virtue of their openness, farming systems are dynamic) and in farmer strategies (Ruthenberg, 1971; Mortimore and Adams, 1999).

A practical way of distinguishing patterns in populations of heterogeneous smallholder farming systems is by stratifying farms into subsets or groups according to specific criteria (Andersen et al., 2007; Van den Brand, 2011). Farm typologies attempt to perform such groupings; the term 'typology' designating both the science of type delineation and the system of 'types' resulting from this procedure (Landais, 1998). The use of typologies has a long tradition in rural sociology (Whatmore et al., 1987) and has attracted the attention of agricultural scientists who create typologies in an attempt to find a meaningful compromise between analysing single farms (no farming system is organized exactly like any other) and assuming broad categories such as smallholders in general.

Farm typologies may be constructed for different purposes; such as to identify diversity and its underlying causes (Gaspar et al., 2008; Tittonell et al., 2005), analyse agricultural trajectories (Iraizoz et al., 2007) or support the development (selection of farms), implementation (targeting and scaling-out of novel technologies or innovations) and monitoring (scaling up of impact assessments) of agricultural development projects (Byerlee et al., 1980; Emtage et al., 2007; Alvarez et al., 2014). Furthermore, farm typologies can focus on different aspects of a farming system; with some looking at differences at field level (Andersen et al., 2007; Carmona et al., 2010; Dossa et al., 2011; Zorom et al., 2013), and others focusing on household-level diversity in resource endowment, for example (Iraizoz et al., 2007; Righi et al., 2011; Tittonell et al., 2010). Finally, different approaches to typology construction can yield different results and this will affect the relevance of the resulting types for all stakeholders involved.

The approach and methodology used to construct a typology is embedded in specific epistemological assumptions which determine the research paradigm (Whatmore et al., 1987). Social scientists and practitioners of participation frequently rely on qualitative evidence, while natural scientists and economists tend to favour 'hard data'. Meanwhile, governments and donors often leave decisions about research approaches to the technical advisers involved in agricultural research and development (Barahona and Levy, 2007). In response to the need to look beyond the conventional, top-down, transfer-of-technology models for agricultural research and extension of the 1990s, which often failed to achieve the required impact for many smallholders in Africa (Chambers and Jiggins, 1987), recent discourse has focused on the potential and limits of alternative participatory approaches (Jones et al., 2014; Kudadjie et al., 2004; Neef and Neubert, 2011; Van Asten et al., 2009).

The epistemological perspectives in the theoretical debate surrounding the development of farm typologies and their utility has been reviewed by Whatmore (1994) who identified three approaches to farm clustering. The first is the taxonomic or 'positivist approach', which defines types based on quantitative data, according to standard scientific protocols with the choice of variables usually determined by the researcher. The second approach is more explanatory and is termed the 'relational approach'; it challenges the dominant positivist approach with its emphasis on the identification of relations between farmers and their contexts to help explain causal processes. The third is the more interpretive yet similarly unorthodox 'folk approach', which incorporates the qualitative, subjective processes (motivations, meaning-making *etc.*) behind the patterns of behaviour, relationships and strategies of the participants into the typology. In the latter, the participants themselves usually determine the criteria for grouping of farmers or farm systems. In a similar vein, Maton et al. (2005) discriminate two kinds of farm typologies: those using 'positivist' methods based on statistical data (Köbrich et al., 2003) and those using 'constructivist' methods based on expert knowledge (Landais, 1998; Girard et al., 2001). Although it is acknowledged that the boundaries between these different frameworks are not rigid, the spectrum of approaches to the study of farm diversity generally has the positivist approach and the folk approach as its extremes (Emtage et al., 2007). The 'etic-emic' distinction employed by anthropologists is particularly useful for further differentiating them.

The positivist approach takes as its starting point theories and concepts from outside of the studied setting, regarded as meaningful and appropriate by scientists ('etic' perspective) (Lett, 1990). Most farm typologies have been constructed within the positivist framework (Whatmore et al., 1987). Farm diversity is studied using quantitative variables that are believed to have strong relations with the variation in the systems under investigation, and clustering arises from multivariate statistical analysis of these variables (for examples, see Bidogeza et al., 2009; Chavez et al., 2010; Tittonell et al., 2010). Strengths of this top-down approach are its reproducibility and transferability (ease of comparison across scales and contexts) (Kostrowicki, 1977). However, by depending on researcher-defined criteria, important drivers of diversity may be overlooked and the identified categories may lack meaning for farmers themselves (Van Averbeke and Mohammed, 2006; Pacini et al., 2014). Obtaining complete quantitative data is often also costly and time-consuming due to the diversity and the complexity of farming systems (Thornton and Herrero, 2001).

In the folk approach, the intent is to discover how members of a system perceive and classify diversity (McKinney, 1969; Sims and Bentley, 2002). Constructs are expressed in terms that are meaningful and appropriate to local perspectives and indigenous knowledge ('emic' perspective) (Lett, 1990) and as a result, data collection tends to emphasize participatory methods (for examples, see Adjei-Nsiah et al., 2007; Kong et al., 2014). The main strength of this qualitative, bottom-up approach is the attention paid to situating the typology in the local context, which provides room for unexpected patterns and concepts to emerge (Jones et al., 2014). For example, the criteria of classification used by farmers usually differ in interesting ways from those used by scientists (McKinney, 1969; Nazarea, 2006). One of the weaknesses of the folk approach is that it lacks the authority of the scientific method. Its subjectivity renders it difficult to measure the identified categories and its specificity makes it ill-suited to generalization beyond its local boundaries (Van Averbeke and Mohammed, 2006). Research using participatory methods may also be costly in terms of resources and time spent by researchers and stakeholders who take part in the studies (Barahona and Levy, 2007; Neef and Neubert, 2011; Röling et al., 2004).

Notwithstanding the somewhat polarized debate on the value of participation for agricultural research and development (Barahona and Levy, 2007; Jones et al., 2014; Sims and Bentley, 2002), participatory approaches have encountered both successes and failures worldwide (Bentley, 1994; Johnson et al., 2004; Lilja and Dixon, 2008; Scoones and Thompson, 1994; Van Asten et al., 2009). Improving the effectiveness of positivist approaches to typology construction by combining participatory methods in a way that will make research more useful for farmers in their own local context remains a methodological challenge (Kudadjie et al., 2004; Neef and Neubert, 2011). Nevertheless, careful integration of expert and scientific knowledge can potentially lead to a more comprehensive understanding of complex and dynamic farming systems

(Righi et al., 2011).

The aim of this study is to compare the positivist (statistical) and folk (participatory) approaches to typology construction. Specifically, we assess the (non-)complementarity of a statistical typology described in Kuivanen et al. (2016) and a participatory typology elaborated in this paper, for characterisation of smallholder farming systems in three intervention communities of an active 'research for development' (R4D) project in Northern Ghana. The statistical typology was generated using recent survey data, and incorporated quantitative variables of farm structure- and functioning. Clustering arose from multivariate statistical analysis of these variables, using the well-known techniques of principal component analysis and cluster analysis. The participatory typology was delineated in collaboration with local stakeholders, using their expert knowledge to establish a common reference base. This paper thus sets out to: *i*) describe the results of the participatory typology; *ii*) compare the variables of the statistical and participatory typologies, and *iii*) analyse the overlap between the systems of farm types. Following this, we reflect on the possible causes of the dis(similarity) between the two approaches and conclude on the insights offered by each approach in the context of agricultural development. It is envisioned that the results will support the more effective design and execution of development interventions and policies that are tailored to the different needs and opportunities of local farmers.

2. Materials and methods

2.1. Project, site selection and data sources

This research was embedded in a multi-country R4D program, Africa Research in Sustainable Intensification for the Next Generation (Africa RISING), supported by the United States Agency for International Development as part of the United States government 'Feed the Future' initiative (http://africa-rising.net/). Operating within a time horizon of five years (2012–2016), the project is being implemented in East and Southern Africa (Ethiopia, Tanzania, Malawi and Zambia) and in West Africa (Mali and Ghana). In partnership with selected intervention communities, Africa RISING aims to create opportunities for smallholder farm households to escape hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, while conserving or enhancing the natural resource base (IITA, IFPRI & ILRI, 2012). The challenge is to achieve these goals while acknowledging smallholder diversity within the project regions and communities. Therefore, identification of farm types is an important first step.

Africa RISING in Ghana is led by the International Institute of Tropical Agriculture (IITA) and the intervention area comprises the three most poverty-stricken geographical and administrative regions in Northern Ghana, namely the Northern Region, Upper East Region, and Upper West Region (Fig. 1). In September 2013, a team of enumerators associated with Africa RISING surveyed 240 farm households across these three regions of Northern Ghana, as part of a baseline study. In each region, 80 household heads were randomly selected from Africa RISING intervention communities for interviews using a structured questionnaire. Basic information on household composition and education of household members, land holdings, livestock ownership, labour use, assets, housing, production orientation, major crops and sources of income was collected. This study makes use of the resulting dataset, but focuses exclusively on the classification of farm households in the Northern Region.

2.2. Characteristics of the case study area

The Northern Region occupies 70 383 km^2 which constitutes over two fifths of the area of Ghana. Divided into 20 districts with the town of Tamale as its regional capital, the region is economically poor with little industry (Kelly and Bening, 2007). Vegetation falls into the Guinea–Savannah zone, which is characterized by vast, low-lying areas of semi-arid grassland interspersed with savannah woodland, a dry and hot climate, uni-modal rainfall and fragile, sandy-loam soils often overlying impenetrable ironpan or laterite (Ellis-Jones et al., 2012; Wiredu et al., 2010). Three Africa RISING intervention communities were surveyed within the Northern Region; namely Botingli (9.61° N 0.79° W, Savelugu-Nanton district $n = 21$), Kpalung (9.68° N 0.78° W, Savelugu-Nanton district, $n = 28$) and Tingoli (9.37° N 1.01° W, Tolon-Kumbungu district, $n = 31$) (Fig. 1). These communities constituted the study area.

The predominant ethnic group in the study communities are the Dagomba (Table 1), who comprise about a third of the population of the Northern region (Ellis-Jones et al., 2012). Their basic unit of social organization is the farm household, physically centred around a 'compound' where the head (typically male) lives with his nuclear or extended family (Al-Hassan and Poulton, 2009; Oppong, 1967). Livelihoods are based on small-scale, low-input, mixed crop-livestock agriculture and villages tend to follow the typical concentric spatial arrangement found elsewhere in Africa, comprised of nucleated human settlements in the middle, inner rings of fertile compound farms, medium distance fields, and outer rings of more distant bush farms (Benneh, 1973; Yiridoe et al., 2006).

According to the traditional land tenure system, arable land inherited by the household head through paternal lineage is fragmented into smaller plots that are allocated to household members (Iddrisu Baba Mohammed, personal communication, September 2014). While responsibility for growing the household's maize staple crop lies with the head and is grown on his plot (the main compound farm), all household members are expected to contribute labour, so as to ensure a basic level of staple food supplies for the domestic unit (Al-Hassan and Poulton, 2009). In addition, household members cultivate different combinations of cash- and food crops on their own farms, which may be sold in the event of surpluses (Table 1). Livestock are kept for food, income, wealth accumulation, sacrificial purposes and to a lesser extent for their supply of inputs such as manure (used as organic fertilizer) and draught power (Ellis-Jones et al., 2012; Sansoucy et al., 1995). The characteristics of the communities are further summarised in Table 1.

2.3. Statistical typology

The Africa RISING survey for the Northern Region comprised information from 80 randomly sampled farm households across the three case study communities, capturing the diversity in local farming systems (Table 2). The dataset was used by Kuivanen et al. (2016) to construct a statistical farm typology.

2.3.1. Variables

From the pool of farm household-level information, 12 variables describing household, labour, land use, livestock ownership and income dimensions were distilled (Table 2). The choice of variables was informed by the findings of previous studies, project objectives and data availability.

2.3.2. Methods

Two multivariate statistical techniques were employed

Fig. 1. Map of the Northern Region of Ghana (inset) showing the location of the Africa RISING intervention communities (red points), Kpalung, Botingli and Tingoli, in Savelugu-Nanton and Tolon-Kumbungu districts.

Table 1
Main characteristics of the case study communities in Ghana's Northern Region (2013 cropping season).

Characteristic	Savelugu-Nanton		Tolon-Kumbugu
	Botingli	Kpalung	Tingoli
Socio-economic			
Population	579	1739	2266
Ethnic groups	Dagomba	Dagomba, Fulani, Frafra and Mamprusi	Dagomba
Religion(s)	Islam and traditional faiths	Islam, traditional faiths	Islam, christianity, traditional faiths
Distance to closest urban centre	3 km	7 km	2 km
Land availability	Scarce	Abundant	Scarce
Access to major markets	Intermediate	Relatively poor	Relatively good
Production activities			
Major food crops	Maize (*Zea mays*)	Maize, yam (*Dioscorea sativa*)	Maize
Major cash crops	Soybean (*Glycine max*) and groundnut (*Arachis hypogaea*)	Soybean, groundnut	Pepper (*Capsicum chinense*), groundnut
Livestock system	Free grazing local livestock breeds (cattle and small ruminants), night corralling	Herding by Fulani, free grazing and night corralling (cattle and small ruminants)	Free grazing local livestock breeds (cattle and small ruminants), night corralling, traction, pig husbandry

sequentially: principal component analysis (PCA) to reduce the dataset into non-correlated principal components (PC's) and cluster analysis for partitioning the PCA output into clusters. For the latter, a two-step approach was followed. First, a hierarchical, agglomerative clustering algorithm using Ward's method was employed to define the number of groups (k), and then a non-hierarchical, partitioning algorithm was employed to refine these k-groups. All analyses were executed in R (version 3.1.0) with the *ade4* package (version 1.6–2, available online at: http://pbil.univ-lyon1.fr/ADE-4/) and the *cluster* package (version 1.15.2).

2.3.3. Results

The results of the multivariate analysis (*i.e.* variable correlations, PC interpretation, farm types) are illustrated in Fig. 2. The PCA extracted the first five PC's explaining about 66% of the variability in the dataset. Six farm types were identified; contrasted by their structural (resource endowment[1])- and functional (production objectives/livelihood strategies) characteristics (Fig. 2E–H, Tables 2 and 4). Types 1 and 2 tended to be the wealthiest; *i.e.* relatively

[1] This refers to wealth-related criteria such as farm size, livestock ownership and household size (Tittonell et al., 2010).

Table 2
Main characteristics and heterogeneity of the farming systems in the case study area ($n = 80$ surveyed farms) and the variables used for their categorization in the statistical typology ('Incl. in PCA') and the resulting farm types (1–6) and their distribution (HRE: High resource endowed; MRE: Medium resource endowed; LRE: Low resource endowed; SRC: Severely resource constrained).

Variable	Unit	Incl. in PCA	Code	Mean	±SEM	Min.	Max.
Household[a]							
Size of household	Number of members	✓	Sizehh	15.2	0.97	4	37
Age of household head	Number of years			48.0	1.61	21	70
Labour							
Total labour input[b]	Hours per year	✓	totlab	2450.5	174.22	256	7048
Hired labour ratio[c]		✓	hiredratio	0.1	0.01	0	0.44
Female labour ratio[d]				0.2	0.02	0	0.57
Land use							
Cropped land area[e]	Hectares	✓	landsize	3.8	0.24	0.81	9.31
Maize ratio[f]		✓	maizeratio	0.5	0.02	0.19	1
Legume ratio[g]		✓	legratio	0.2	0.02	0	0.68
Tuber ratio[h]				0.1	0.02	0	0.51
Other cereal ratio[i]				0.1	0.01	0	0.33
Livestock ownership							
Herd size	TLU[j]	✓	tottlu	3.2	0.39	0.15	17.31
Cattle ratio[k]				0.2	0.04	0	0.93
Small ruminant ratio[l]		✓	rumratio	0.6	0.04	0	1
Poultry ratio[m]		✓	poultryratio	0.2	0.03	0	1
Food security and income							
Food self-sufficiency[n]	Months per year			6.6	0.36	1	12
Crop sales[o]	Percentage	✓	cropsales	36	3	0	86
Livestock sales[p]	Percentage	✓	livsales	21	2	0	76
Off/non-farm income[q]	Percentage	✓	offincome	16	2	0	70

Type	Main characteristics	Proportion in survey
1	HRE, large cattle herd, ample off/non-farm activities	11%
2	HRE, large farms, market orientation	10%
3	MRE, small ruminants, on-farm labour intensive	13%
4	MRE, small ruminants, ample hired labour	46%
5	LRE, maize-dominated, few off/non-farm activities	14%
6	SRC, livestock sales, ample off/non-farm activities	6%

Source: authors' analysis of the 2013 survey data. In all the Tables and Figures that follow, the source remains the authors unless otherwise specified.
[a] A 'farm household' within Africa RISING is defined as a group of people that work and live at least half of the time on the farm and operate under the leadership of a household head (IITA, IFPRI & ILRI, 2012).
[b] Family, hired- and exchange labour input for crop production (the sum of all reported labour per plot per household).
[c] Share of the total labour which is hired (hired labour/total labour input).
[d] Share of the total labour which is undertaken by women (female labour/total labour input).
[e] Land used by farmers for crop production (the sum of all reported plot sizes per household).
[f] Share of arable land cropped to maize.
[g] Share of arable land cropped to legumes: soybeans, groundnuts, cowpeas.
[h] Share of arable land cropped to roots and tubers: cassava and yam.
[i] Share of arable land cropped to other cereals: rice, sorghum, millet.
[j] Tropical Livestock Unit: livestock conversion factors based on Jahnke et al., 1987.
[k] Share of cattle in total TLU (herd).
[l] Share of small ruminants in total TLU (herd): goats and sheep.
[m] Share of poultry in total TLU (herd): chickens, ducks, turkeys, pigeons and guinea fowls.
[n] Months of the year when household food demands are met by on-farm production.
[o] Share of crop products sold on the market.
[p] Share of livestock products sold on the market.
[q] Share of income derived from off/non-farm activities.

well-endowed in terms of land, livestock and human resources. Type 1 comprised large households endowed with sizeable cattle herds, medium sized maize-based farms and high levels of income diversification into non-farm sectors such as trading. Type 2 was represented by households with relatively large farms cropped primarily to maize and legumes. Income was mainly generated through the sale of cash crops, making this type the most market oriented. Types 3 and 4 were characterized by moderate levels of resource endowment. Type 3 comprised labour-intensive medium- to large farms dominated by maize and legumes. Livestock consisted mostly of small ruminants. Type 4 was the largest group and it exhibited structurally similar farming systems to those of Type 3, except on a smaller scale; making it more land and labour-limited. Types 5 and 6 encompassed low resource endowed farm households. Type 5 was particularly land-constrained, characterized by small farms dedicated to maize production for household consumption and almost no income-generating off/non-farm activities. Type 6 was the smallest group and represented the most poorly-endowed households, with small herds dominated by poultry, and income procured from livestock sales combined with low-paid off-farm activities. Finally, the types were validated by a local expert (former agricultural extension officer for the Northern Region). Additional details on the multivariate analysis and resulting typology are provided in Kuivanen et al. (2016).

2.4. Procedure to construct the participatory typology

Towards the end of the cropping season in September 2014, the three Africa RISING intervention communities included in the 2013 baseline survey for the Northern Region were approached for collaborative formulation of a participatory typology of farming systems. Inspired by the Participatory Learning and Action

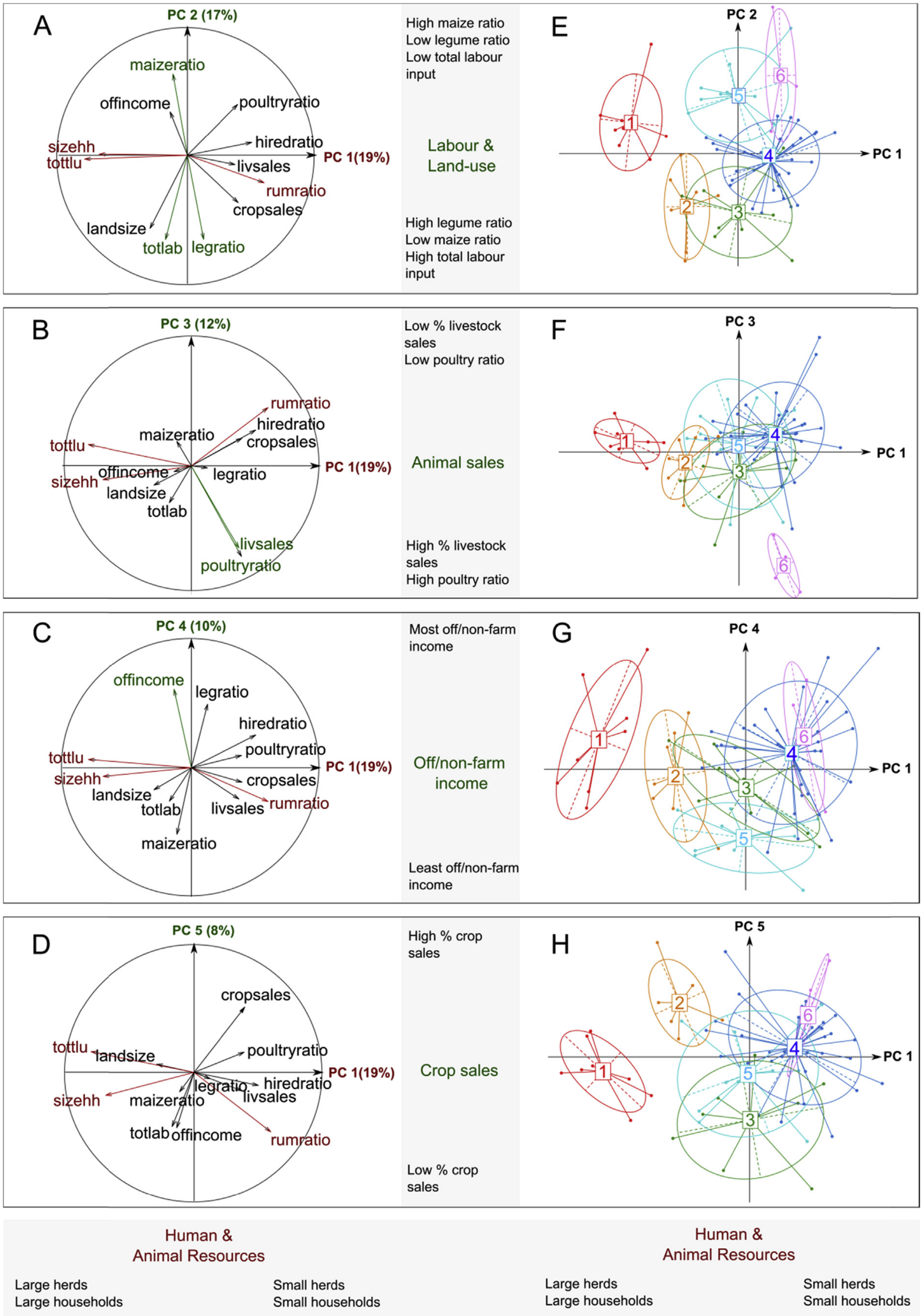


Fig. 2. Output of the PCA and cluster analysis: circles of correlation (A–D) and farm types 1–6 (E–H) in the planes PC1-PC2, PC1-PC3, PC1-PC4 and PC1-PC5. The directions and lengths of arrows within the circles show the strength of the correlations between variables, and variables and PC's. The arrows highlighted in red represent those variables that correlate strongly (>0.60) with PC 1, whereas the arrows highlighted in green represent those variables that correlate strongly with each subsequent PC. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)
Source: Kuivanen et al. (2016).

approach for learning about- and engaging with communities (Pretty et al., 1995; Salomon and Engel, 1997; Lynam et al., 2007) and working closely with a native-speaker translator who also possessed an intimate knowledge of local farming systems, a procedure was developed comprising four mutually supporting steps, referred to here as: 'introduction', 'simple exploration', 'complex exploration' and 'convergence'. The procedure was piloted in two non-survey villages before being adjusted and executed in each of the three target communities in turn. The steps are summarised below.

2.4.1. Step 1: introduction

An introductory meeting in each community served as a platform to present the research objectives and request the cooperation of the chief and villagers. With the help of a translator, facilitator and other community members, these meetings were also used to identify 10 'key informants' (henceforth referred to as 'farmers') per village who represented a cross-section of the population in terms of status, age, gender and ethnicity. These key informant farmers fulfilled the necessary condition of possessing "common knowledge" (knowledge shared by the members of communities) of local farming systems (Barahona and Levy, 2003). To gain a preliminary understanding of the study area, focus group discussions were held with the 10 farmers, where the history, demographic makeup, social structure, production, off/non-farm activities, land tenure system and public services of the communities were discussed (*c.f.* Table 1 for a partial summary).

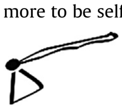
2.4.2. Step 2: simple exploration

Participatory resource mapping was conducted with the farmers to reveal the community's perception of how physical space and resources were used. The maps provided a valuable visual representation of socio-cultural, institutional and natural features such as sacred sites, school buildings, water bodies, livestock enclosures and arable fields. In addition, the mapping activity stimulated reflection and discussion around the link between resources in the community and the farmers as resource users. The exercise served as a primer for the following step.

2.4.3. Step 3: complex exploration

The different types of farming systems that exist in the communities were identified from an emic perspective. This entailed breaking down the concept of 'farming system' into its more tangible sub-components (*e.g.* household, cropping activities, livestock). The first activity thus involved delineation of categories of difference in an open brainstorming session with all 10 key informants, guided by idiomatic 'can-openers' (Gotschi et al., 2009) such as: 'We look at the fingers on our hands and see that each one is different. As the fingers on our hands are different; so the [farms/farmers/crops *etc.*] of [Botingli/Kpalung/Tingoli] are different. What are the differences that you see amongst yourselves?' (translated from the vernacular). The differentiating criteria that emerged from this were recorded on a flipchart and then used in a sequential manner, first classifying farming systems according to the most salient criterion/criteria and then subdividing classes on the basis of other relevant criteria. The discussion was facilitated so that a useable set of categories were agreed upon.

Table 3
The main characteristics of the five farm types determined using participatory methods (HRE: High resource endowed; MRE: Medium resource endowed; LRE: Low resource endowed; SRC: Severely resource constrained).

Type	Symbol[a]	Main characteristics	Type prevalence in the communities[b]	Proportion in the survey
A	 'Household heads are always happy and smiling'	*Pukparkara* ('Big farmers, men'): HRE (large farm size), market-orientation	++	8%
B	Fist and outstretched hand indicate that 'what these farmers have is not enough, they need more to be self-sufficient'	*Pukparsagsa* ('Medium farmers, men'): MRE (medium farm size), variable production orientation	++++	52%
C	 The hoe symbolizes that the farmers 'cannot afford to hire the services of a tractor'	*Pukparbihi* ('Small farmers, men'): LRE (small farm size), subsistence orientation	+++	40%
D	 The cooking pot and cutlass are 'tools used by women'	*Pagba pubihi* ('Small farmers, women & children'): LRE/SRC (small farm size), market orientation	+++++	0%
E	 The ear suggests that the 'farm-less always listen out for work opportunities'	*Suhukpion* ('Farm-less, men'): work on other farms as hired labour	+	0%

[a] Examples of farm type symbols.
[b] Relative proportion of each type: + (very small); ++ (small); +++ (medium); ++++ (large); +++++ (very large).

Table 4
Summary of the main characteristics of the (S) statistical typology (resulting from PCA) and (P) participatory typology (farmer-defined).

Variables	S	P	Statistical typology						Participatory typology				
			Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type A	Type B	Type C	Type D	Type E
Demographic													
Household size and composition	✓	✓	Large: 17–34 persons	Medium: 9–24 persons	Medium: 9–30 persons	Variable: 4–37 persons	Variable: 6–33 persons	Small: 6–16 persons	Large, extended, polygamous	Variable: 6–30 persons	Variable: 2–10 persons	N/A	Single person
Age, gender, status		✓							Older men, incl. household heads	Older men incl. household heads and male youth	Older men incl. household heads and male youth	Women and children	Men of variable age
Labour													
Total labour input	✓		Medium	High	Highest	Low	Low	Lowest					
Family & exchange/ Hired labour	✓		Mostly family	Mostly family	Medium share of hired labour	Largest share of hired labour	Medium share of hired labour	Medium share of hired labour					
Cropping system													
Farm size (average)	✓	✓	Medium (3.6 ha)	Largest (6.3 ha)	Large (5.2 ha)	Medium (3.5 ha)	Smallest (2.5 ha)	Small (2.6 ha)	Large >4 ha	Medium 0.8–4 ha	Small 0.4–2 ha	Smallest 0.1–0.4 ha	Farm-less 0 ha
Land use and production orientation	✓	✓	Maize based	Legume and maize dominated	Legume and maize dominated	Legume and maize dominated	Maize dominated	Maize dominated	Mainly cash crops, high yields	Food crops and cash crops	Mainly food crops	Mainly cash crops, intercrop low yields	N/A
Inputs and equipment		✓							Improved seed, fertilizers + tractor	Improved seed, fertilizers + animal traction	Fertilizer + Hoe and cutlass	Hoe and cutlass	N/A
Postharvest storage		✓							Large grain huts	Medium grain bins	Bags	Bags and pots	N/A
Self-sufficiency		✓							Yes	Variable	No	N/A	No
Livestock													
Herd size and main composition	✓		Largest herd (cattle)	Large herd (cattle)	Medium herd (small ruminants)	Small herd (small ruminants)	Medium herd (small ruminants)	Smallest herd (poultry)					
Socio-economic													
Main income sources	✓		Non-farm income	Crop sales	Crop and livestock sales	Crop sales	Crop and livestock sales	Off-farm income and livestock sales					
Dwelling type		✓							Zinc roofed	Variable	Thatch roofed	N/A	N/A
Income investment		✓							Motorbike, tractor, livestock, business	Services (tractor and transport), livestock	Bicycle, food, inputs	Household necessities, inputs, education	Variable
Personal characteristics		✓							Wear good shoes, eat meat, happy	Dress decently and children are healthy	Parents quarrel a lot, children look hungry	Variable	Lazy, fast living, big spender

Next, a commonly agreed-upon symbol which captured a representative feature of each category was assigned to these identified 'farm types' (*c.f.* Table 3). Following this, the characteristics of each farm type were expounded. Additional farmer-defined secondary criteria were recorded in a matrix and where possible, for each identified criterion the different type-specific levels and quantitative ranges were obtained (*c.f.* Table 4). For the purposes of comparison with the statistical types, farmers were also asked to describe the farm types in terms of additional criteria according to a checklist based on Table 2 (*c.f.* Supplementary Material for detailed descriptions of the types). The final activity involved assigning the 80 farms included in the baseline survey to the identified types. Cards were labelled with the name of the reference person of each sampled household (typically the male household head) and given to the farmers to classify one by one by placing them in the appropriate pile on the matrix. The farm types, their prevalence in the communities and relationships to each other were discussed.

2.4.4. Step 4: convergence

A transect walk was chosen with farmers to traverse the main land use systems of the village. This enabled a visit to representative farms of selected farm types identified in step 3, and cross-checking of some criteria by direct observation (*e.g.* dwelling type, *c.f.* Table 4).

2.5. Comparison of the typologies

In order to assess the (non-)complementarity of the positivist (statistical)- and folk (participatory) approach, we first compared the variables resulting from the PCA and differentiating criteria determined collaboratively with farmers. We then calculated the overlap between the farm household classifications as a measure of the (dis)similarity between two given groupings (Martin et al., 2001).

3. Results and discussion

3.1. Comparison of the statistical and participatory typology

3.1.1. Participatory typology

Capturing farm diversity through the analysis of typologies is a key step in the design of agricultural development strategies, interventions and policies that are tailored to the local context. Combining local expert and scientific knowledge in typology construction can lead to a more comprehensive understanding of the multiple dimensions of farming systems (Righi et al., 2011). In this study we compared two different approaches to the characterization of smallholder farming system diversity in Northern Ghana; a positivist (statistical) typology described in Kuivanen et al. (2016) and a folk (participatory) typology.

An important result of the participatory typology was the adoption by farmers of the 'individual' (*i.e.* plot holder or farmer) as the unit of analysis. On the other hand, in the statistical typology the unit of analysis was the 'farm household'. Nevertheless, for the sake of simplicity, we continue to refer to the statistical- and participatory types as 'farm types'.

Delineation of a participatory typology of farming systems in collaboration with local farmers resulted in three community-specific typologies comprising five farm types in Botingli, three types in Kpalung and five types in Tingoli. In all communities, the most salient differentiating criterion was that of 'farm size'. The four most frequently identified criteria were 'farm size', 'gender' (of plot holder), 'age' (of plot holder) and 'income investment' (Table 4). This enabled synthesis of the community-specific typologies into one global typology for the case study area comprising five farm types, each represented by selected farmer-defined symbols (Table 3). Several other secondary criteria were identified and these are summarised in Table 4.

Characterization of the resulting farm types revealed that Types A-C exhibited a trend similar to that demonstrated in the statistical typology: the gradient in farm size (representing resource endowment) tended to be positively related to high-value crop production and asset ownership; considered to be proxies for wealth (Chapoto et al., 2013; Negash and Niehof, 2004; Tittonell et al., 2010). The farmers' estimates of the relative proportions of these types in the study communities seemed to indicate that moderately endowed Type B constituted the second-largest group followed by resource-constrained Type C, while well-endowed Type A farmers represented only a small minority. Types D and E were unique to the participatory typology. Type D comprised the wives and young children of the farmers belonging to Types A-C and therefore constituted the largest cluster in the communities. Type E, on the other hand, constituted the smallest cluster in the communities and comprised 'farm-less' men. In the strictest sense, the latter group should not be categorized as a farm type as its members owned no farm and their source of livelihood was mainly off-farm. However, they are included in the result due to their being recognized by the farmers as a distinct group of (deviant) individuals/farmers that nevertheless form part of the community (Table 3; Supplementary Material).

3.1.2. Comparison of variables

Different variables/criteria were selected for statistical- and participatory clustering. While the PCA results used for clustering in the statistical typology tried to merge variables into a smaller number of dimensions, so that the clustering reflected an analysis of combined explanatory variables; in the participatory typology the criteria were used in a sequential manner first classifying farmers according to farm size and then subdividing classes on the basis of other relevant criteria. Some variables that had discriminatory value in the statistical typology were weakly represented in or absent from the participatory typology and *vice versa* (Table 4). Some of the variables had similar descriptive names, but their underlying meaning diverged due to interpretation as well as cultural differences, while others had different descriptive names, yet their underlying meaning converged. In the following paragraphs, the selection and representation of variables employed in the construction of the typologies is analysed.

3.1.2.1. Demographic. The variable of 'household size' was used in both typologies and proved to be a strong descriptor of wealthier Type 1 and Type A, associated with larger households (Table 4). The demographic criteria of 'household composition', 'gender', 'status' and 'age' (of plot holder) were included in the participatory typology, but not considered for delineation of statistical types. This is mostly due to the different units of analysis *i.e.* the farm household as a whole for the statistical typology *vs*. individual farmers for the participatory typology. In the participatory group discussions, farmers viewed 'gender' as a key determinant of farm size and differentiated between larger farms owned by men and smaller farms cultivated by women. In addition, the participatory process revealed that 'status' and 'age' were positively related and also exhibited strong discriminatory power: farmers distinguished older men (*e.g.* senior household heads), younger men and children. Finally, 'household composition' described the make-up of the domestic unit within which farmers were embedded. Distinctions were made between smaller nuclear, larger extended, polygamous and non-polygamous farm households.

3.1.2.2. Labour. Labour was an influential factor in the statistical typology, in particular the 'total labour input' variable rather than the 'hired labour ratio' variable (Fig. 2A; Table 4). Labour was not directly identified by farmers as a differentiating criterion, but was indirectly alluded to via the analogous criteria of 'agricultural equipment' and 'farm size'. 'Agricultural equipment' differentiated between farmers who used hoes and cutlasses, draft animals and tractors, thus constituting a rough indicator of the labour input associated with manual *vs.* mechanized land preparation and other tillage practices. Secondly, the delineation of farm types based primarily on the criterion of 'farm size' resulted in a 'farm-less' category of men who worked exclusively for wages off-farm and in non-agricultural activities (see Supplementary material). This category in itself was therefore indicative of a certain type of labour(er) that existed in the communities, as distinct from household labour, exchange labour and farmers who occasionally hired themselves out as seasonal labour.

3.1.2.3. Cropping system. The farm or *puu* was defined as the area of inherited land that a farmer cultivated (uncultivated areas were not considered to be part of the farm) (Iddrisu Baba Mohammed, personal communication, September 2014). It was described by farmers as the cornerstone of Dagomba livelihood; 'without a farm, you are nothing'. Furthermore, according to farmers; the difference in farm sizes was the most defining feature of the farm systems in the communities (Table 3). It was explained that the size of the plot allocated to an individual depended on a number of factors such as access to resources (*e.g.* family- and market labour), gender of ownership (women and children were restricted to smaller farms) and the physical capabilities of farmers (related to age and health status). Interestingly, the strong discriminatory power of 'farm size' in the participatory typology was not reflected in the statistical typology, where the corresponding variable of 'cropped land area' only displayed a relatively weak correlation with PC 2 (Fig. 2A). Furthermore, the participatory clustering process revealed that resource endowment, specifically farm size, was positively related to wealth-indicating socio-economic criteria such as 'income investment' and 'dwelling type'. This is not surprising, considering that expansion of the farm area is often the principal means of increasing yields (and saleable output) in low-input, land-constrained systems (Negash and Niehof, 2004; Ohene-Yankyera, 2004).

Although both typologies included various criteria to describe the cropping system, it seems that this dimension was more important for differentiating between farm types in the participatory typology. In the statistical typology, the quantitative variables of 'maize ratio', 'legume ratio' and 'percentage crop sales' (Table 2) corresponded to the qualitative 'crop types' and 'production orientation' criteria selected for participatory classification (summarised under 'Land use and production orientation' in Table 4). 'Crop types' described the different crops (food- and cash) cultivated on a farm and their estimated yields, while 'production orientation' provided some clues about on-farm income sources by differentiating between the proportions of cash crops and food crops cultivated by farmers. In addition to these, the participatory typology also included criteria such as 'cropping practices' (sole cropping, mixed cropping or inter-cropping; summarised under 'Land use and production orientation' in Table 4), 'agricultural equipment' (use of tractors, animals, hoes or cutlasses for tillage), 'agricultural inputs' (access to- and usage of mineral fertilizer, agrochemicals and improved seed) and 'postharvest storage' (traditional grain bins *vs.* pots or sacks). It was explained that farmers who had access to inputs were able to increase farm productivity, thus distinguishing them from those with more limited access, and thus lower yields.

Provision of food for the family was the responsibility of the household head, and food that could not be sourced on-farm had to be purchased (Al-Hassan and Poulton, 2009; Oppong, 1967). Therefore, we consider farm size to be critical for household food security (*c.f.* Ohene-Yankyera, 2004). By extension, it is argued that the level of seasonal food self-sufficiency enjoyed by a farm household is an important indicator of farm size, thus justifying the inclusion of 'self-sufficiency' as a differentiating criterion by farmers. Possibly due to farmer misestimation of seasonal food availability during survey data collection, no clear relationship between food self-sufficiency and the different farm types was found in the statistical typology (Kuivanen et al., 2016).

3.1.2.4. Livestock. While livestock features were key descriptors in the statistical typology, during the participatory process farmers did not include animal numbers, types or husbandry practices in their criteria for discriminating between farm types in any of the communities (Table 4). This apparent omission of livestock-related criteria may be partly explained by the traditional centrality of crop farming to Dagomba cultural identity (Iddrisu Baba Mohammed, personal communication, September 2014). Although livestock ownership has historically played a role in Dagomba livelihood strategies; manure exchange- and herding arrangements with Fulani were common until recent times (Bellwood-Howard, 2012). Nevertheless, the animal component was acknowledged in the descriptive phase of participatory typology formulation, where farmers were asked to further elaborate on the characteristics of each identified type. This revealed a positive relationship between farm size and livestock ownership: apart from animals acquired through inheritance, ownership of livestock was dependent on purchase using income generated from surplus crop product sales. Similarly to the statistical typology; herd size and composition varied between the types (see Supplementary material), with cattle being an especially good descriptor of farmer endowment (Laube, 2007; Marchetta, 2013).

3.1.2.5. Socio-economic. Livelihood strategies were described in both typologies using income-related criteria (Fig. 2B–D; Table 4). In the statistical typology, variables were included that differentiated the income sources among households (Table 1). In the participatory typology, discrimination between food-and cash crops (represented by the 'crop types' and 'production orientation' variables) provided an indirect indication of the diversification strategies among farmers; with those oriented mainly towards cash crop cultivation assumed to derive more income from crop sales. Conversely, because livestock acted as a store of value and were rarely sold except in times of extreme shock such as crop failure or famine (Laube, 2007), such farmers were assumed to be less likely to depend on the sale of livestock for income. The omission of farmer-defined criteria related to off/non-farm activities may be partly attributed to the socio-cultural emphasis placed on agriculture as well as the relative dearth of non-farm opportunities in Ghana's Northern Region (Chamberlin, 2008). Average dependence on off/non-farm income sources was found to be quite low among the surveyed farmers who seemed to rely more on their farm enterprise for income (Table 2).

Unequal levels of farmer financial endowment were represented by the unique socio-economic criteria of 'income investment', 'dwelling type' and 'personal characteristics' in the participatory typology. 'Income investment' described differential levels of farmer asset ownership (*e.g.* tractors, motorcycles and livestock) as a result of investment choices. In the statistical typology, farmer wealth investment was represented by the variables associated with 'livestock ownership' (Table 2). 'Dwelling type' described physical differences in household compound structures by discriminating between traditional huts of mud-brick and

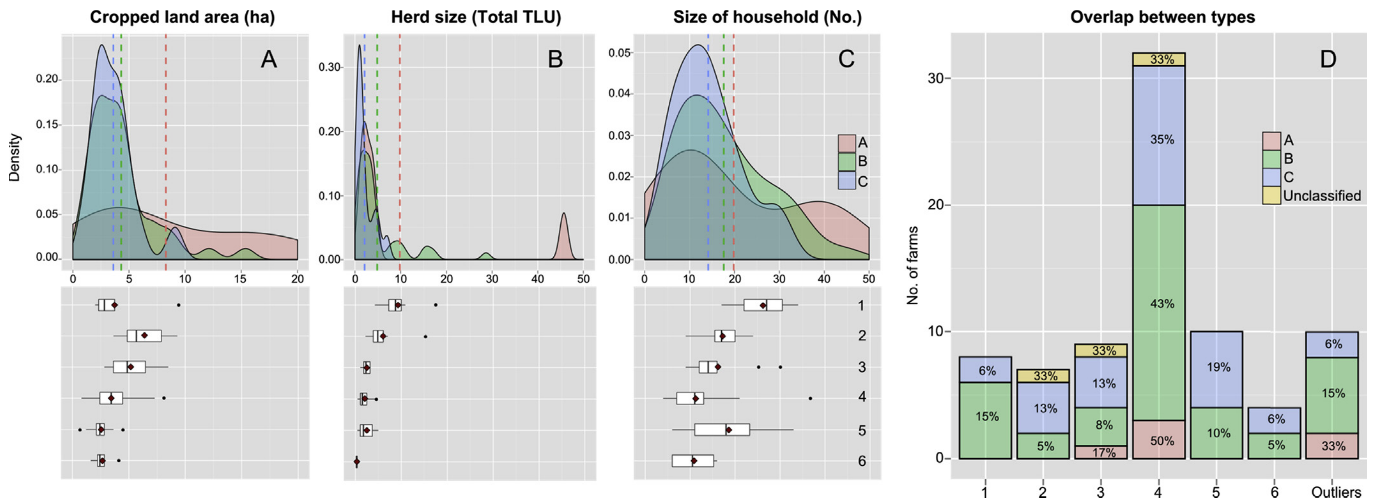


Fig. 3. Participatory ($n = 77$ farms including 3 unclassified farms) and statistical ($n = 70$ farms including 10 outliers) typology overlap: kernel density curves per participatory farm type (dashed lines representing the group means) and boxplots per statistical farm types (coloured point representing the group means) for the variables of cropped land area (A), herd size (B) and household size (C); and histogram showing the distribution of the participatory types across the statistical types (D). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

thatch construction, and modern concrete and zinc structures. Modern compounds were considered to be more expensive to build and associated with well-endowed farmers (*c.f.* Pellow, 2011). Finally, 'personal characteristics' described the highly subjective, more intangible perceived differences in signifiers of health, personality and clothing style of farmers, which were understood to be positively related to wealth.

3.1.3. Classificatory overlap

The third step in the procedure for constructing the participatory typology ('complex exploration') required farmers to position the head of each household included in the baseline survey within the identified system of farm types. This facilitated later comparison of the types and allowed for an analysis of the overlap, *i.e.* (dis) similarity between assignments to types when comparing the statistical and participatory classifications.

First, we reorganized the survey data into the participatory farm types, and computed mean values of selected variables for each type in the statistical and participatory typologies. Comparison of these 'mean profiles' showed some similarity in terms of the inherent structure of the types: the means of selected variables for the participatory Types A, B and C were found to roughly correspond to the means of the same variables for the associated statistical types. For example, type-specific mean values for the variables of cropped land area, herd size and household size tended to be lowest for resource-constrained Types 5, 6 and Type C, and highest for the wealthier Types 1, 2 and Type A (Fig. 3A–C). This seems to imply that the general trends captured by the statistical typology were validated by the participatory typology.

Nevertheless, subsequent examination of the distribution of the participatory farm types across the statistical farm types revealed limited overlap when comparing the two typologies, with medium-endowed, statistical Type 4 tending to englobe almost half of the surveyed farm households (Table 2) and three of the participatory types (Fig. 3D). More specifically; the households associated with the small share of wealthier household heads assigned to Type A in the participatory typology (Table 3) were not distributed within the corresponding well-endowed statistical Types 1 and 2, as would have been expected. However, they were to be found in the medium-endowed Types 3 and 4 as well as amongst statistical outliers (Fig. 3D). More than half of the sampled household heads were identified by farmers as belonging to moderately-endowed Type B (Table 3); yet only 43% of the associated households were statistically classified as medium-endowed Type 4, while the rest were distributed amongst the other five statistical types (Fig. 3D). Furthermore, farmers assigned 40% of the sampled heads to poorly-endowed Type C (Table 3). However, only 25% of these were statistically determined as representing the corresponding resource-poor households of Types 5 and 6 (the rest were assigned to the wealthier Types 1, 2, 3 and 4). Finally, and perhaps most obviously; as the reference system of the survey included household heads who were invariably male farmers, none were classified in the unique categories of female/children (Type D) and farm-less (Type E) in the participatory typology (Table 3).

3.2. (Dis)similarity between the farms types

Although there are numerous advantages of using farmer knowledge in scientific research, discrepancies between farmer and researcher observations may occur (Van Asten et al., 2009). The overlap between the two typologies was limited due to a range of factors: differences in the grouping approach and units of analysis, inaccuracies in the data, changes that occurred between the two data collection efforts, misidentification of household heads for classification in the participatory typology and deletion of farms as outliers during statistical analysis. These are further elaborated in the following paragraphs.

3.2.1. Approach and units of analysis

The grouping approach was fundamentally different for the statistical- and the participatory typology and this had important implications for the resulting farm types. The positivist approach of the statistical typology required measurable, quantitative data which was obtained through a structured survey; leaving intangible dimensions such as social relationships, personal characteristics of farmers *etc.* only partially represented (*c.f.* Randall and Coast, 2014). By contrast, the folk approach of the participatory typology enabled face-to-face contact and open dialogue with the farmers themselves, and the participatory farm types emerged from a host of small questions (bottom-up) rather than starting with a focus on the system itself (top-down). This emic approach yielded information that is difficult to capture in standard surveys;

as illustrated by the socio-culturally-relevant symbols assigned to each type which served to summarise the farmers' perspectives and also provide insight into the kind of conceptual framework farmers use to organize their realities (McKinney, 1969) (Table 3).

Furthermore, the different units of analysis (household *vs.* individual farmer) on the basis of which the typologies were constructed contributed to mismatch between the classifications: in the statistical typology, a given household was allocated to a farm type on the basis of information provided by the head himself; whereas in the participatory typology the surveyed household heads were assigned to farm types based on the perceptions of key informants. While surveys have the practical advantage of aggregating data at a household level (through the lens of a single reference person), they may lead to a poor representation of reality, particularly in the context of more complex, extended and/or polygamous domestic units such as those commonly found in the study area (Budlender, 2003; Randall and Coast, 2014). Thus, by not interviewing multiple respondents within the household, the survey rendered certain categories of people less visible; such as those whose main occupations and income sources were off the farm, and women and children (*c.f.* Doss et al., 2013). For example: the wife and children associated with a resource-rich, male head would appear to be a wealthy household and classed as Type 1 in the statistical typology. The participatory typology, on the other hand, would classify the women and children as relatively resource-poor Type D. The latter approach thus provided a more nuanced differentiation, making allowance for the co-existence of multiple farm types in a single farm household and acknowledging potentially important target groups for the R4D project that were not included in the statistical typology, such as female farmers (Type D) and 'farm-less' men (Type E).

Nevertheless, as evidenced by a common trend in the gradient of resource endowment among types, the typologies also shared some aspects of inherent structure (*i.e.* similar mean profiles; *c.f.* 3.1.3). This complementarity between the types may be explained by the fact that the units of analysis, while telling different stories, were not divorced from each other: an individual (farmer) is usually embedded in a household.

3.2.2. Data inaccuracy

Data collected in the survey did not fully reflect reality for other reasons which include: misunderstanding by farmers of questions posed by enumerators, the difficulty of estimating quantitative variables (*e.g.* farm sizes, livestock numbers, age *etc.*), the spatially dislocated (fragmentation of farms and animal herds) yet socially interconnected context, local socio-cultural norms and the perceived social distance between farmers and enumerators. For example, farmers assigned a household defined as moderately endowed (Type 3) in the statistical typology to a wealthier group (Type A) in the participatory typology. It was explained that the household head in question had inherited a medium-sized farm but had enlarged the area through land borrowed from neighbours. However, only the part of the farm that had been acquired through inheritance had been recorded in the survey. Similarly, it was claimed that the same farmer possessed a sizeable herd of cattle, despite this not being apparent from the survey. This was attributed to the fact that his cattle were often tended to by relatives outside of the community. Related to the previous point, farmers explained that cattle were commonly inherited by male members of the descent group and herds were considered to be the joint property of the inheritors, making it improper for any single inheritor to 'claim' sole ownership. The tendency for farmers to downplay cattle numbers was also linked to the lingering legacy of a historical taxation system which penalized farmers with large animal herds (Iddrisu Baba Mohammed, personal communication, September 2014).

Moreover, Dagomba society is hierarchical, and deference towards those of higher rank or status is expected (Oppong, 1967). During participatory classification; cultural and social (power) issues tended to distort the assessment of household heads, some of whom were considered to be of high social standing, such as the councillors to the chief (*e.g. tamalnaa*, *wulana*, *zoonaa*), the sub chief (*zakyurinaa*), community elders, religious leaders, teachers and ranked members of the traditional warrior class. It is possible that farmers may have felt obliged to show their respect for these individuals by assigning them to 'superior' types, despite the information collected in the survey revealing otherwise.

Finally, the Dagomba saying; '*ashili nyedoo*' ('secrets make a man') illustrates what appeared to be a general reluctance among community members to reveal personal information. This seemed to hold particularly true when dealing with 'outsiders'. Farmers explained that while they were distrustful of the intentions of strangers perceived as *karachi* (educated), they were also aware of the possibility of achieving (short-term) benefits from such interactions: 'If I say I am fine, then I won't be helped'. This may have led to cases of deliberate misrepresentation of farm household situations during both survey interviews and participatory discussions.

3.2.3. Structural changes

Typologies, unless regularly updated, do not reflect the dynamic nature of farming systems or the movement of types in time (Iraizoz et al., 2007; Landais, 1998). Therefore, changes to farm structure (*e.g.* farm size or herd size) that had occurred in the communities in the year between survey data collection and participatory analysis with farmers, may have contributed to classification discrepancies. In an example that highlights the importance of the socio-historical context of farm performance for determining type membership; a household classified as moderately endowed (Type 4) in the statistical typology was assigned to well-endowed Type A in the participatory typology. The farmers justified this decision by explaining that the household head in question was known to consistently cultivate large tracts of land, but that at the time of the survey had been forced to temporarily downsize his cropped area as a coping strategy in the face of unexpected crop failure.

Farmers emphasized this fluidity in discussions during the participatory sessions. It was remarked, for instance, that moderately-endowed Type B continuously absorbed farmers into its ranks and that the rate of 'regression' from resource-endowed Type A to moderately-endowed Type B was higher than the rate of 'progression' from resource-constrained Type C to Type B. Indeed, Type B and Type 4 encompassed the largest share of surveyed household (heads) in the participatory- and statistical typology respectively, many of which appeared to be 'borderline cases' that did not fit neatly into the more narrowly defined extreme types. This heterogeneity may partially account for the dispersion of Type B farms across the statistically defined categories and the apparent encapsulation of all the participatory types in Type 4 (Fig. 3).

3.2.4. Misidentification of farm households

Incorrect identification of the sampled household heads by farmers during 'complex exploration' (step 3) may have resulted in misclassified cases. Households were assigned to participatory types on the basis of the officially recorded, full names of their heads. This turned out to be problematic; as some household heads shared the same name, or were known to members of the community only by their nickname. This was partly addressed by referring to secondary identifiers recorded in the survey, such as tractor or television ownership. On occasion, farmers retracted their classification decisions on the premise that the household head had been misidentified. In total, 3 households remained unclassified due to doubts concerning their identity.

3.2.5. Data screening

To avoid distortions in the multivariate analysis, outliers were deleted from the survey dataset. Results of the overlap analysis seemed to suggest that some of the wealthiest farm households were expunged in the data screening process of statistical analysis as outlying observations, for example due to herd sizes which surpassed the researcher-defined cut-off point of 20 TLU. For the most part, farmers assigned the household heads associated with these statistical outliers to well-endowed Type A and moderately-endowed Type B. Interestingly, it was noted that households with herd sizes larger than the attributed threshold also exhibited farms of well above average size and were situated in the community of Kpalung, where land and the services of Fulani herdsmen were reported to be more readily available than in the communities of Botingli or Tingoli (Table 1).

4. Conclusions

This research was carried out in response to a call for the design and implementation of situated agricultural development interventions and policies that take into account local farming system diversity. We compared two contrasting approaches to the characterization of farming systems in three intervention communities of an active R4D project in Northern Ghana: a quantitative, statistical typology based on household-level survey data and multivariate analysis, and a qualitative participatory typology based on group sessions and participatory activities with selected key informants. The statistical typology provided a general impression of the main structural- and functional features underpinning farm variation, while the participatory typology resulted in a more nuanced analysis of diversity at the level of individual plot holders (farmers).

Our study showed dissimilarities in both type delineation and the resulting systems of types between the approaches. In the statistical typology the unit of analysis was the 'farm household', and multivariate analysis led to the identification of six farm types. Types 1 and 2 were the wealthiest, Types 3 and 4 were characterized by moderate levels of resource endowment, and Types 5 and 6 encompassed poorly endowed farm households. Formulation of a participatory typology resulted in five types, based on the 'individual' as the adopted unit of analysis. Types A-C exhibited similar trends to those found in the statistical typology; the gradient in endowment among these three types tending to be positively correlated with wealth indicators such as high-value crop production and asset ownership. Types D and E, on the other hand, were distinctive to the participatory typology and comprised the wives and young children of the farmers assigned to Types A-C and 'farm-less' men, respectively. Furthermore, different variables were selected for statistical and participatory clustering. While the PCA results used for clustering in the statistical typology tried to merge variables into a smaller number of dimensions, so that the clustering reflected an analysis of combined explanatory variables; in the participatory typology the criteria were used in a sequential manner first classifying farmers according to farm size and then subdividing classes on the basis of other relevant criteria. Finally, analysis of the overlap between assignment of surveyed household (heads) to types when comparing the statistical and participatory classifications revealed discrepancies. These were attributed to a number of factors such as differences in the approach and units of analysis, inaccuracies in the data due to interpretation and socio-cultural (power) issues, changes that occurred between the two data collection efforts, misidentification of household heads for classification in the participatory typology and deletion of farms as outliers during statistical analysis.

We conclude that while the use of statistical techniques warrant objectivity and reproducibility in the analysis, the complexity of data collection and representation of the local reality might limit their effectiveness in selection of farms and of innovation targeting and out-scaling in R4D projects. In addition, while participatory typologies offer a more contextualized representation of heterogeneity, their accuracy can still be compromised by socio-cultural constraints, epistemological differences between local and scientific knowledge domains, as well as the perceived social distance between farmers and researchers, for example. For both statistical and participatory typology approaches, the dynamic nature of farms and households, with changes that can occur either gradually or as discrete events, should be addressed more explicitly to remain relevant and effective in R4D projects. Therefore, neither the reliance on local experts as information sources, nor structured surveys are sufficient for the comprehensive understanding and analysis of complex and diverse farming systems by themselves. We concur with recommendations made elsewhere to make effective use of the advantages offered by both approaches by integrating them (Alary et al., 2002; Den Biggelaar and Gold, 1995; Pacini et al., 2014; Righi et al., 2011). Although engaging in participatory work takes time and effort; if employed prior to statistical approaches, the rich insights it provides may help to focus scarce resources on relevant activities and enhance the quality of research (for example in the selection of more appropriate variables to use in multivariate analysis, improved survey design, *etc.*). Using qualitative methods in addition to quantitative tools also provides a solution for working with incomplete available data, while ensuring that contrasting but complementary information from both emic and etic perspectives are included in the final output.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jrurstud.2016.03.015.

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