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Hohenheim Working Papers on Social and Institutional Change in Agricultural Development

Working Paper 016-2023

Agricultural Input Use in Nigeria: Consistency, Complementarity, and Credit

Malik Olaoye

Universität Hohenheim

August 2023

Hohenheim Working Papers on Social and Institutional Change in Agricultural Development (016-2023)

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Authors Details

Malik Olaoye (University of Hohenheim, Germany)

Corresponding Author

Malik Olaoye (malikolaoye@gmail.com)

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Suggested citation: Olaoye, M. Agricultural Input Use in Nigeria: Consistency, Complementarity, and Credit. Hohenheim Working Papers on Social and Institutional Change in Agricultural Development 016-2023. University of Hohenheim.

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Abstract

There are complex synergies between different agricultural inputs and practices. For example, improved seeds reach maximum yields only in combination with fertiliser, and fertilisers may have limited effects without adequate weed control, which may necessitate the use of herbicides. Yet, agricultural inputs are often promoted to address single constraints of smallholder farmers without taking into account such agronomic synergies.

In an earlier paper, Sheahan & Barrett (2017) found "a surprising dearth of synergistic use of modern inputs" in Africa, which they describe as an untapped potential. This study assesses input use in Nigeria using three waves (2010 – 2016) of the agricultural-focused household-level LSMS-ISA panel dataset (Living Standard Measurement Survey – Integrated Surveys on Agriculture) from the World Bank. The research explores whether Nigerian farmers use modern agricultural inputs, such as fertilisers, herbicides, pesticides, purchased seeds, and irrigation, synergistically or as stand-alone inputs. Additionally, the study investigates the consistency of input use, or whether farmers "move in" or "move out of" using some inputs, throughout 2010-2016. Lastly, the study analyses the effect of credit on using inputs individually and complementarily with logit and Poisson panel regression models. The study found that Nigerian farmers mostly use inputs individually, with fertilisers being the most utilized input. In the Northwest of Nigeria, about 70% of plots applied fertilisers, which was the highest share nationwide. Complementary use was low, with herbicides and fertilisers being the most jointly used inputs, accounting for 20% of plots on the national level. Consistency of input use ranged from moderate to low. Fertilisers and purchased seeds were used by 47% and 50% of households in at least two waves, while the consistency of other inputs' use was lower. Credits were found to have varying impacts depending on the input and the administrative zones. The type of credit (formal or informal) also mattered for some inputs. Other factors affecting input use included the types of crops (cash crop or food crop), non-farm income, and extension services. Credit was found to be relevant for the complementary use of inputs in Nigeria, and the interaction terms of credit and extension were correlated with using inputs (including fertiliser). The study recommends that agricultural policies regarding credit and inputs should be considered on a zonal or local level rather than nationally. Furthermore, extension services promoting the benefits of using agricultural inputs complementarily should also be promoted.

Key Words

LSMS-ISA, plot-level panel data, upset plots, agricultural input policies

Acknowledgments

The author is grateful for the financial support from the "Program of Accompanying Research for Agricultural Innovation" (PARI), which is funded by the German Federal

Ministry of Economic Cooperation and Development (BMZ). In addition, the author appreciates the support and guidance of Dr. Christine Bosch during the study, the efforts of Dr. Thomas Daum in making this working paper possible and Professor Dr. Regina Birner for her supervision. Thank you!

1. Introduction

1.1. Background to the Study

The agricultural sector is a crucial sector for the Nigerian economy. Despite the oil focus, agriculture remains the most important sector for development in Nigeria. The industry employs over 60% of the country´s workforce, implying that the majority of households derive their livelihood from agriculture (Osabohien et al., 2020), most of which are in the rural areas (81%), where the majority of the agricultural activities are carried out (World Bank, 2014). Given the country´s underwhelming development level (especially in the rural areas), agriculture has been one of the sectors at the forefront of the development plans. All the federal government administrations since the start of democratic rule in 1999 have committed to the development of the agricultural sector, as it is considered one of the most critical sectors for the country´s growth and development (Eze et al., 2010). For agriculture to serve its role as the medium for development, the sector's total production must increase among other things like improved labour productivity, a vast reduction in the number of people in agriculture, migration towards urban areas, and more (Collier & Dercon, 2014).

In achieving the production increase, various factors are essential, including increasing public spending on the sector (Kenny & S O, 2019), improved market access, and an increase in the use of modern agricultural inputs (Sheahan & Barrett, 2014). McArthur & McCord (2017) investigated the impact of agronomic inputs in cereal yield improvements. They found that fertilisers, modern seeds, and water play a clear role in increasing production. Agrochemicals such as herbicides and pesticides also increase agricultural productivity when used correctly (Aktar et al., 2009; Kughur, 2012). Kidane et al. (2013) compared the efficiency of production between tobacco in which more agricultural inputs have been applied, and cereal crops such as maize, groundnut, and rice, using the frontier production approach. They found that tobacco was more efficient than the cereal crops. They mentioned that if the cereal farmers applied just as many agricultural inputs, the results would have differed in favour of the cereals. It is clear that using these inputs at the optimum level increases farm productivity and efficiency. Therefore, the expectation is that they should be widely utilized in any country that considers agriculture important.

Sheahan & Barrett (2014) showed that in Sub-Saharan Africa, agricultural inputs are used more than initially thought, although still at a lower rate than in developed countries. They utilized the Living Standard Measurement Survey – Integrated Surveys on Agriculture (LSMS-ISA) data set in analysing the level of input use in Ethiopia, Malawi, Niger, Nigeria, Tanzania, and Uganda. For Nigeria, they reported that 41.4% of households used inorganic fertilisers. On the other hand, about 3.4% of households utilized organic fertilisers. They indicated that this could be because the data was collected for only composite manure, and the organic fertiliser usage value might be lower than it is. About 33% of households used other agrochemicals, including pesticides, herbicides, and fungicides. The use of purchased seeds was the highest for maize, with 24% of cultivating households using purchased seeds. These input usage values are considerably higher than reported values before the micro-level LSMS data set became available. They explained that this could be because macro-level analysis has been the most common way to calculate national statistics on input use, and the extrapolations and assumptions might have led to the inaccuracy of the previous reports.

1.2 Knowledge Gaps and Objectives

Sheahan & Barrett (2014) carried out a detailed descriptive analysis of the level of input use in Nigeria, but they only used one wave of the LSMS data set. Subsequently, more waves of the dataset have been published, and it should be interesting to analyse the input use over a more extended period. Additionally, they did not go into an extensive analysis of the underlying factors affecting inputs' use.

Adjognon et al. (2017) saw this missing piece and decided to use the first and second wave (2010/2011 & 2012/2013) of the LSMS dataset to dig deeper into how inputs are financed and how credit plays a role in Nigeria. The input usage values are only slightly different from the results of Sheahan & Barrett (2014), but it is interesting to see an increase in usage. Adjognon et al. (2017) also found that receiving credit (formal and informal) for inputs purchase is still relatively low. Nigerian farmers mainly finance fertiliser purchases through income from non-farm activities.

Additionally, it has been reported that using agricultural inputs complementarily is essential for maximizing the productivity and efficiency gains from using these inputs (Naeher, 2017). Although insights into these synergistic usages of inputs are limited due to too little focus in the inputs use conversation.

This study takes the research one step further by using three waves (2010/2011, 2012/2013, and 2015/2016) of the LSMS data set in assessing the input use landscape. To describe the usage consistency, which gives insight into how farmers use inputs over time. It shows if Nigerian farmers move in and out of inputs or not. The LSMS data set also allows us to describe the complementary input usage at the plot level and household level, giving us more insights into input usage dynamics. To see whether farmers that have adopted are using inputs synergistically or as substitutes. It goes one more step further to analyse how Nigerian farmers finance these inputs, similar to Adjognon et al. (2017) with some additions. As initially stated, three waves of the LSMS datasets were utilized. The effect of credit was analysed for fertilisers, pesticides, herbicides, and purchased seeds. The role of credit in a household's ability to use more inputs (complementary use) was also included. The following research questions were answered in this research.

1. What is the extent of complementary agricultural inputs use in Nigeria from 2010-2016?

2. How consistent are Nigerian farmers' in using inputs (analyzing data from 2010-2016)?

3. What proportion of Nigerian farmers receives credit, and how does credit correlate to inputs use (single-use and complementary use)?

The first two research questions were answered using descriptive statistics, and only the third research question required hypotheses.

1. H0: Household member receiving credit is not related to using fertiliser

2. H0: Household member receiving credit is not related to using herbicides

3. H0: Household member receiving credit is not related to using pesticides

4. H0: Household member receiving credit is not related to using purchased seeds

5. H0: Household member receiving credit is not related to using inputs complementarily

1.3. Definition of Terms

- Inputs / modern agricultural inputs: This represents agricultural inputs mentioned in the study: Fertilisers, agrochemicals (herbicides and pesticides), improved seeds, and irrigation.
- Consistency: This implies the continuous application or use of these inputs by households in all waves of the data analysed.
- Complementary and Joint use: This represents the use of more than one input on a single plot and more than one input by a household. Complementary use and joint use were used interchangeably.
- Purchased seeds: This is used as a proxy for improved seeds
- Agricultural equipment: This includes tractors and equipment such as planters, harvesters, and ridgers

2. Literature Review

2.1. Brief background of Nigeria

According to the United Nations World Population Prospects, Nigeria has over 200 million people, with about 60% of the working class directly or indirectly involved in agriculture (World Bank, 2014). Agriculture is an important economic activity for Nigeria in her quest for inclusive development. In the 60´s and 70´s, agriculture was the major contributor to the nation’s GDP. However, the focus switched to oil, leading to a steady decline of agriculture’s contribution to the GDP, pushing it down to second place (Abubakar & Ibrahim, 2019). Nonetheless, it remains an important sector for development in Nigeria. It currently employs most of the working population, especially in rural areas, where 80% of the people in poverty reside (World Bank, 2014). Nigeria has a considerable amount of viable land for farming, spread across the country's diverse expanse, but only about 40% is cultivated (Omorogiuwa et al., 2014). The underutilization of viable land is due to several factors such as soil quality depletion, agricultural practices like bush burning and shifting cultivation, and farm distance to market (Andrew, 2016). As Nigeria is still not self-sufficient in producing food that she should produce and still ranks very low in the global hunger index and food security index, agricultural production should be more than it currently is (Abubakar & Ibrahim, 2019). The utilization of modern agricultural inputs will ensure that uncultivated land due to quality depletion can be put under cultivation again, and the soil quality of presently cultivated pieces can be maintained. Additionally, farms in areas with a good road network and reasonable distance to the market can improve their productivity, thereby supplying more to the market.

Olukunle (2013) mentioned that the prevalent subsistence production system, low productivity, technology adoption level, and small return on investment inhibits the agricultural sector. In the paper, more of the sector's challenges were explained in detail. More importantly, in relevance to this research, the technical constraint and unstable inputs and outputs prices were discussed. The paper showed that the manifestation of the constraints is seen in the low level of inputs used due to the high costs of inputs, the high level of poverty predominant among Nigerian farmers (Mufutau, 2010), and the inadequate availability of financing opportunities. These are all issues that should be sorted out for Nigeria´s agricultural sector to reach its full potential.

Nigeria is divided into six geopolitical zones to provide more specific solutions to societal issues and regional policies. The division is mainly based on geography, although cultural and ethnic considerations have been made for a more fitting classification. The administrative zones / geopolitical zones are North Central, North West, North East, South West, South East, and the South-South.

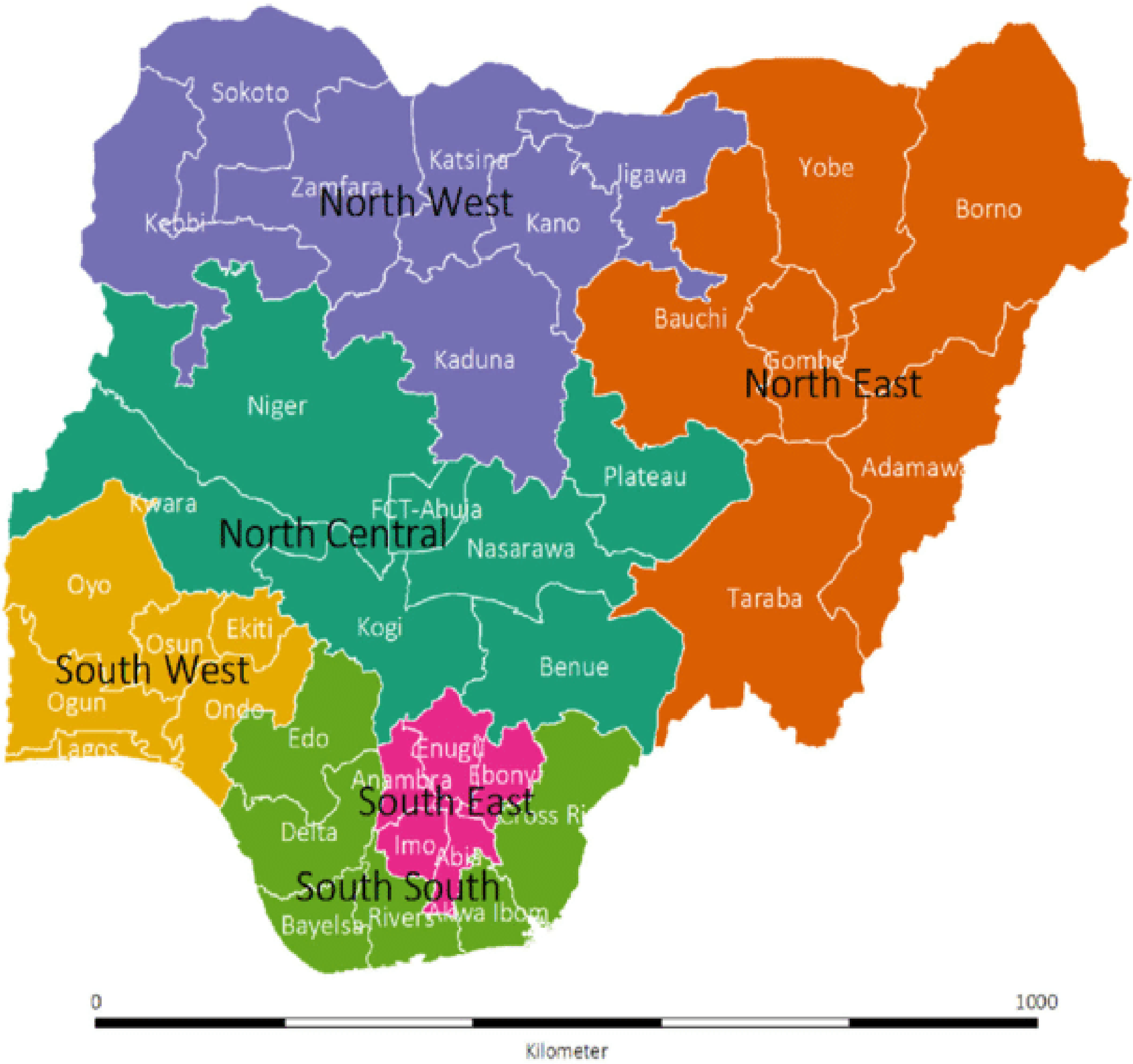

Figure 1. Administrative zones in Nigeria

Source: Wong et al. (2018)

The geopolitical zones are related to the agroecological division in that as we move up North, it becomes hotter, less humid, and rainfall reduces. The agroecological map of Nigeria is shown below.

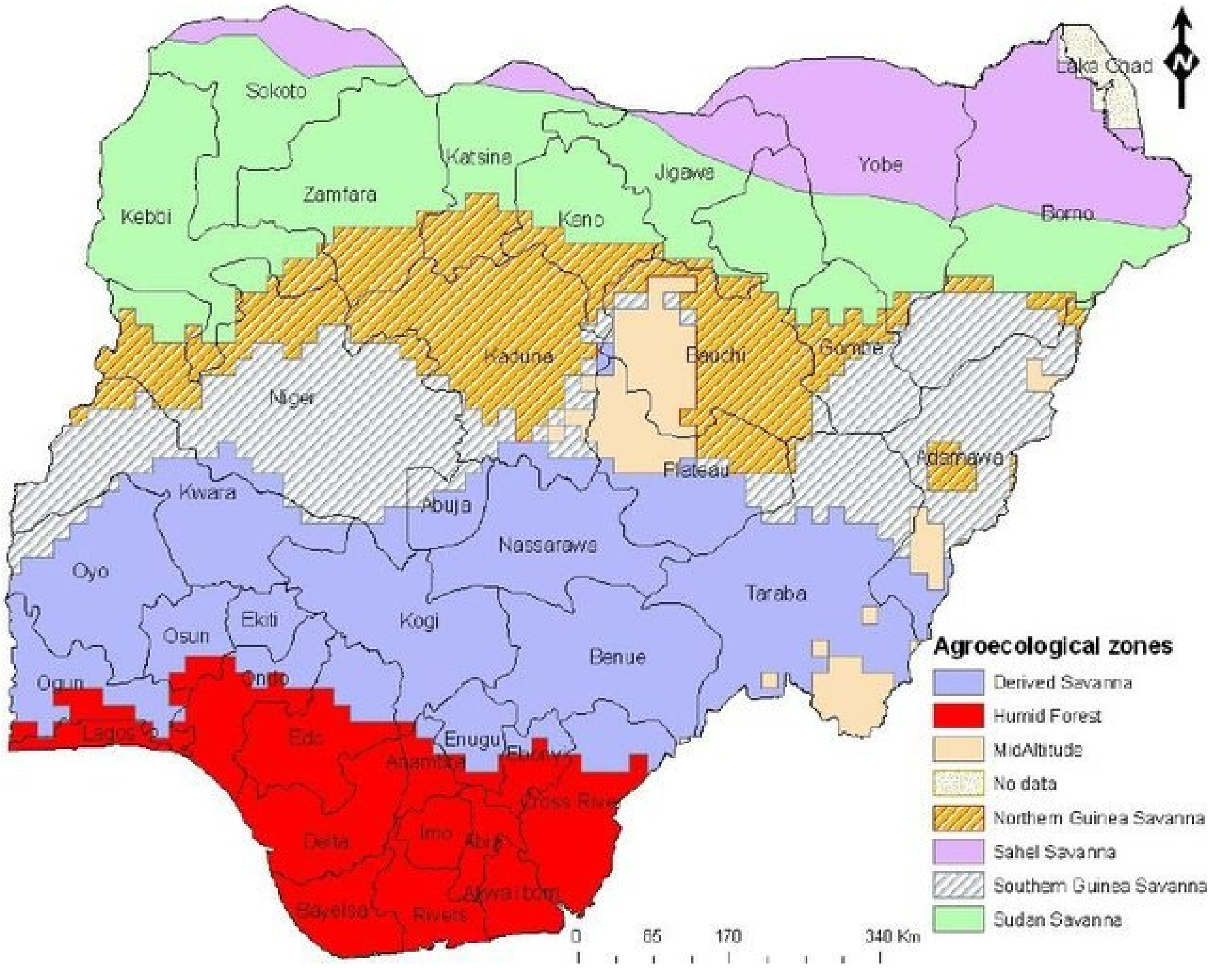

Figure 2. Agroecological zones and states in Nigeria

Source: Alamu et al. (2013)

This agroecological classification is expected to have implications for the predominant agricultural practices, vegetation, and crops planted in different zones. Lower rainfalls and shorter rainy seasons characterize the Northern zones compared to the southern zones; therefore, 80% of Nigeria's vegetation zones are situated there. The southern zones are humid with longer rainy seasons. They are the tropical rainforest zones of Nigeria; plantation crops such as cocoa and oil palm are supported by these characteristics (Oniosun, 2013). Staple crops such as yam, cassava, and sweet potatoes are also supported.

Oniosun (2013) also presented the predominant cropping systems and common crops in the different agroecological zones. In the Sahel Savanna, mixed cropping is the prevailing cropping system, and the dominant crops are peanuts, beans, and maize. Mixed cropping is also predominant in the Sudan Savanna, and millet, sorghum, peanuts, and beans are the common crops. In the Northern Guinea Savanna, crop rotation is the prevailing cropping system, and cotton, durra sorghum, maize, and shea nuts are the predominant crops. Mixed farming is the most common system in the Southern Guinea Savanna, and the most common crops are rubber and durra sorghum. Mono cropping is the most common cropping system in the Mid-altitude region, and carrot, maize, and millet are the common crops. In the Derived Savanna, mixed cropping and crop rotation are the predominant cropping systems, and cassava, cocoa, and maize are the common crops. Lastly, the Humid forest zones are characterized by rubber, oil palm, yam, and cassava. The most common cropping system there is also mixed cropping. The predominant cropping system in the different zones does not vary greatly, as we see that mixed cropping is quite common. The main difference is in the dominant crops. The differences are marginal between zones close to each other, and most times, they have similar common crops. However, the differences are more apparent when we look from North to South; it is expected that this will affect the types of input used and the level of application based on the crop requirements from North to South.

Furthermore, the federal ministry of agriculture and natural resources reported that the soil quality varies from the Northern zones to the Southern zones. The Northern zones (the Guinea Savanna, Sudan Savanna, and Sahel Savanna) are characterized by slightly acidic, coarse, shallow surface soil with higher clay content than the southern zones. They also have low organic matter content (less than 2%) and low total nitrogen content (less than 0.1%). On the other hand, the Southern zones (Derived Savanna and the rain forests) have deep sandy loam topsoil rich in organic matter content, free iron, and higher Nitrogen content than the Northern zones(FMANR, 1990).

2.2. Current Level of Input Use in Nigeria

2.2.1. Fertiliser

Fertiliser use in SSA has been recorded as low Bumb & Gregory (2006). An increase in usage is paramount due to the largely depleting soil nutrient composition. Bumb & Gregory (2006) reported that Nigeria's national average depletion rate was greater than 60kg/ha in a year. Although the paper also clarified that the average national depletion rate does not tell the full story and there are significant variations nationally, this implies that the use of fertiliser in Nigeria is of great importance to ensure productivity increase.

Several papers have shown that fertilisers are the most used inputs in Nigeria (Akramov, 2009; Sheahan & Barrett, 2014). Akramov (2009) reported that almost 50% of farming households use agricultural inputs, with over 42% of them using fertiliser, but just about 7% and 10% use improved seeds and pesticides. Fertilisers can be either organic or inorganic, but due to the absence of a market for organic fertiliser, there is sparse national-level data on the usage. Therefore, most nationally representative statistics focus on just the use of chemical/inorganic fertilisers. However, Sheahan & Barrett (2014) and Akramov (2009) used different household level data sets from varying years. They reported similar levels for fertiliser usage in their paper. Still, the considerable differences across administrative zones for all modern agricultural inputs point to zonal variations for each of these inputs. The northern zones utilize more fertilisers than the southern zones (Sheahan & Barrett, 2014). Akramov (2009) presented the share of inputs used by households across the geopolitical zone. We see that over 80% of households in the North West use modern agricultural inputs while only about 16% in the South-South use them. These zonal differences could be due to the soil fertility differences, rainfall differences, the types of crops majorly planted, and government policies, as we will see in this chapter's policy subsection below.

2.2.2. Herbicide and Pesticide

Herbicides and pesticides are chemical inputs used in crop protection against weeds and pests, respectively. Evidence on the use of agrochemicals is limited and difficult to interpret. This difficulty is due to the lumping together of different agrochemicals and the unclear use of the terms. For example, Adekunle et al. (2017) mentioned that most of the pesticides (should have been agrochemicals) used were herbicides, stating that 89.3% of the surveyed farmers used them, and 20% and 18.3% used fungicides and insecticides, respectively. They noted that this is because the farmers in the study area faced more issues with weeds than pests. It is important to note that most of the literature regarding the usage of agrochemicals (herbicides and pesticides) in Nigeria has been focused on the negative health impact of misusing these inputs. This focus is not necessarily misplaced. Although the use of agrochemicals can be beneficial for plant growth and yield increase, Aktar et al. (2009) and Adekunle et al. (2017) reported that 48% and 61% of the surveyed farmers used the insecticide Lindane and Monotocrophous while 55% used the fungicide Ridomil plus (Mancozeb). Agrochemicals that have been either banned in some countries for their adverse health implications or grouped by the World Health Organization (WHO) into the hazard classification class. Even though agrochemicals' health implications are not the focus of this research, it is worth mentioning. It is reasonable to expect that it has an implication on the level of use.

The use of herbicides and pesticides in Nigeria was reported by Sheahan & Barrett (2014). They found that 33% of surveyed households in 2010/2011 used agrochemicals (herbicides or/and pesticides), and more specifically, 21.9% used herbicides while 18.2% used pesticides. Herbicides being the most used conforms with the findings of Adekunle et al. (2017). Without differentiating between herbicides and pesticides, Sheahan & Barrett (2014) also reported the level of agrochemical usage across administrative zones. They noted that most households that used agrochemicals were in the North East with 55% while the South East had the lowest use with 7% of households. Most of the households that used agrochemicals were situated in the Northern part of the country, while the zone with the highest rate of use is the South West with 39% of households. This might be due to the effective methods of controlling pests and diseases for the different types of crops grown in the zones (cereals, legumes, root and tubers, and plantation crops).

2.2.3. Improved Seed

The most extensive set of micro-level data available on agriculture in Nigeria (LSMS-ISA dataset) includes questions regarding the purchase of seeds but not on the varieties of seed farmers used. However, most of the crops planted in Nigeria are improved seeds, but farmers plant them for too long without replacement due to the low quantity available and high purchase cost (World Bank, 2014). This report justifies that most of the seeds sold in the market are improved and that most farmers who purchased seeds are most probably buying improved seeds.

Takeshima & Nagarajan (2015) also reiterated that the use of improved seeds is low in Nigeria, even though the involvement of private actors in the formal seed sector is considerably more than in most African countries. They mentioned that these private actors mainly deal in urban areas due to low profitability in the rural areas. Since most Nigerian farmers are rural farmers, the public supply is constrained in supplying adequately. Their paper also mentioned an informal sector where farmers buy and sell local seeds that are better suited to the local conditions, especially since improved seeds might require complementary use of other inputs to be worthwhile. This angle casts doubt on the relationship between improved and purchased seeds assumed by the LSMS-ISA survey.

As far back as 2006, Daniel & Adetumbi (2006) reported that the majority (71% -100%) of the maize farmlands across the different zones in their research used improved varieties, whereas only 29% used local varieties. Looking into the usage patterns, about 50% of the farmers used seeds from the previous harvest. Sheahan & Barrett (2014) reported from their analysis of macro-level FAO data that in 2009, 95% of total land cultivated with maize was cultivated with an improved variety. This level of adoption was the highest amongst all Sub Saharan African countries in their analysis. Other crops such as cowpea and millet had lower rate of adoption at 39% and 35% of cultivated land in 2009, respectively. As a note, the adoption rate for maize was an over 100% increase from the rate of use in 1998 which was 40%. Now it is almost 12 years from 2009, it will be interesting to see how widespread the use of improved seeds in other crops are today.

Now that the connection between improved seed and purchased seeds has been established, and we have also glanced at the most recent national-level statistics on improved seeds, we now look at the national level statistics available for purchased seeds. Sheahan & Barrett (2014) reported the percentage of households that used purchased seeds in Nigeria. Their analysis showed that using purchased seeds as a proxy for improved seeds use in a single year might also give a much smaller value than the reality. For example, the percentage of households that used purchased maize seeds was only 24% (Sheahan & Barrett, 2014), comparing this to the FAO stat in Sheahan & Barrett (2014), the difference cannot just be due to the level of analysis (plot level to household level). Farmers using improved seeds from the previous harvest is also a viable reason for this difference (Uduji & Okolo-Obasi, 2018), although this is not known with certainty. Additionally, at the regional level, more households used purchased seeds in the Northern zones as compared to the southern zones(Sheahan & Barrett, 2014).

2.2.4. Complementary Input use in Nigeria

Several researchers have made a case for an increase in agricultural productivity by using the modern agricultural inputs jointly on plots rather than individually. Nyangena & Juma (2014) analysed the impact of using improved seeds and fertilisers among maize farmers in Kenya. They found that adopting the two inputs as a package yielded more productivity than adopting just one of the inputs or not adopting any at all. Sheahan et al. (2013) assessed the profitability of fertilisers' individual application instead of adopting a complementary approach to inputs use and farm management strategies in Sub Saharan Africa, using Kenya as a case study. Using a national micro-level data set focusing on maize farmers, they concluded that fertiliser improves maize's profitability for most the farmers, albeit with differences depending on varying characteristics such as rainfall and input and output prices. In relevance to this study, they mentioned that some farmers already apply more than the optimal amount of fertiliser required. In order to improve efficiency, the complementary use of inputs and farming strategies such as soil testing, deep placement application, reduction of soil acidity, and proper plant population should be considered a focus for government policy interventions.

The of use inputs in the following pairings has been reported as beneficial; organic and inorganic fertilisers, inorganic fertilisers and herbicides, inorganic fertilisers and improved seeds, and irrigation with inorganic fertilisers and improved seeds (Ellis, 1993; Nyangena & Juma, 2014; Place et al., 2003; Rosegrant et al., 2014; Vanlauwe et al., 2010, 2011; Yilma & Berger, 2006). Furthermore, Sheahan & Barrett (2014) reported the correlational probabilities of using inorganic fertiliser, organic fertiliser, improved seeds, agrochemicals, irrigation and own agricultural equipment on household and plot level. They showed that there is a high correlation (>50%) between the use of agrochemicals and inorganic fertilisers together in households that used inorganic fertilisers in Nigeria. Other highly correlated conditional use patterns were inorganic fertilisers with irrigation for households that irrigated, inorganic fertilisers with own agricultural equipment for households that used own agricultural equipment, and agrochemicals with irrigation for households that irrigated. Interestingly, on the plot level, only the following pairings were highly correlated: inorganic fertilisers with agrochemicals for plots applied with agrochemicals, agrochemicals with inorganic fertilisers for plots applied with inorganic fertilisers, inorganic fertilisers with irrigation for irrigated plots, and agrochemicals with irrigation for irrigated plots. Nothing was reported for improved seeds since the LSMS data set only has data on purchased seeds for Nigeria. Complementary use of inorganic fertilisers and agrochemical seems to be the most complementary input use. More than 50% of about 41% of Nigerian farmers do this, indicating that when farmers who did not use inorganic fertilisers are included, the two inputs' level of complementary usage is just around 20% (Sheahan & Barrett, 2014).

2.3 Factors affecting input use in Nigeria

The last few subsections focused on detailing the current state of inputs use in Nigeria, both individually and complementarily. This subsection will focus on literature related to the reasons or factors affecting Nigeria's input use, enabling us to understand the reason for the usage level detailed above.

Reardon et al. (1999) used the economics concept of fertiliser demand function (an economic concept consisting of variables that affect fertiliser demand) to split the factors that might affect the adoption and use of fertilisers into two groups (the incentives and the capacity factors). Examples of incentive factors were yield response rate and prices, while capacity factors include household and community level factors that might impact the farmers' ability to purchase fertiliser. Even though these factors can stand alone, in many cases, their combinations are what affects fertiliser adoption and use in Sub Saharan Africa (SSA). Reardon et al. (1999) reviewed several case studies across countries in SSA (Malawi, Nigeria, Gambia, Tanzania, Zambia, Kenya, Congo, Ethiopia, Rwanda, Senegal, Mali, Niger, and more) to illustrate the most common patterns or direction these factors take in impacting fertiliser use. For the incentive factors, the first factor was land scarcity, i.e., human pressure on land. They detailed how increasing land scarcity can lead to increased fertiliser use and how this might change depending on the farm size, types of crop cultivated, and farmer´s access to input credit, market, and road. Secondly, they discussed the farmers' perceptions of yield response as another overarching factor, noting that farmers perception is subjective. However, it can be influenced by the following factors: Extension, complementary input use (especially with regards to the use of improved seeds), and the agroclimatic condition. Another factor is the influence of prices on farmers' perception, mentioning the constituents of effective price: market price, unobserved transaction cost, and opportunity cost. Moreover, farmers will use more fertiliser if the relative price of output increases. Additionally, they discussed the effect of the price elasticity and the relationship between the different types of fertilisers, especially the positively related relationship between phosphorous (P) and Nitrogen (N) in Africa. They added that the price of complementary (irrigation, labour, and improved seeds) and substitute inputs such as organic fertilisers influences fertiliser demand. Interestingly, organic fertilisers and inorganic fertilisers are considered complementary inputs today (Chianu & Tsujii, 2005).

Capacity factors mentioned in Reardon et al. (1999) include access to financial capital, which can be access to credit, income from cash crop sales, and non-farm income. Also, they included access to human capital and information such as level of education and extension. Lastly, they added access to quasi-fixed capital, such as equipment and water control infrastructure such as irrigation. They concluded that these factors are all positively related to the adoption and use of fertilisers in Sub Saharan Africa.

Chianu & Tsujii (2005) investigated the determinants of adoption and non-adoption of inorganic fertilisers in the savannahs of northern Nigeria. Socioeconomic variables such as level of education, age of the farmer, and household food security were all found to affect the adoption rate. The level of education and household food security had a positive relationship with adoption, and farmer's age was negatively related. They also noted that farmers mention lack of access to and lack of credit facilities and the high costs of inorganic fertilisers as some of the reasons for not using fertilisers at the recommended level. Additionally, the authors found that the probability of using inorganic fertilisers increases with the use of organic fertilisers, explaining that this might be an outcome of farmers that are enlightened on the yield benefits of applying both.

Maiangwa et al. (2010) found that farmer's age, farmer's level of education, household size, farmer group membership, farm size, obtaining credit, off-farm income, and receiving extension are all factors affecting the adoption of chemical (inorganic) fertilisers in the Northwestern region of Nigeria. They discovered several local differences in the signs of the significant factors, and they provided a depth of explanation supporting the different directions. For example, the coefficient of farmers' age was both negative and positive in different local regions. They cited papers that have yielded results corroborating the two outcomes. A positive relationship implies that older farmers are more experienced and more open to adopting chemical fertilisers. For the negative coefficient, they explained that younger farmers are planning for a longer time horizon, incentivising them to invest in adopting newer technologies. Household size had a negative relationship with adoption; they stated that this is because larger households are more concerned about food security and more exposed to bad planting seasons due to climate or other factors. So, they would prefer to invest less in adopting new farming technologies than smaller farming households. Education resulted in a positive and negative outcome depending on the local region; they cited papers explaining that this is due to education making farmers more knowledgeable about good agricultural practices. On the other hand, it can open them up to other sectors of the economy or aspect of agriculture that they consider more lucrative than agriculture, therefore deterring them from investment in adopting new farming technologies. Farmer group membership had a statistically significant positive relationship with the adoption of chemical fertilisers; they stated that this could be due to increased access to innovative technologies, market, extension and credit. Farm size and credit also had positive relationships. Off-farm income resulted in both negative and positive coefficients. They explained the positive coefficient to be an impact of the increase in income, allowing the farmers to be able to purchase the input, while the negative relationship could be because the farmers consider the non-farm business to be more lucrative, therefore more important than the farming business. Interestingly, extension also resulted in negative and positive relationships depending on the local region. The positive relationship is understandable as the farmers have access to more information about the fertilisers; the explanation given for the negative relationship was that the farmers' contacts with extension workers might have opened them to more lucrative business other than crop farming. This paper allows us to see the different relationships found with some of these factors affecting input use.

Akpan et al. (2012) used a maximum likelihood estimation model to investigate the factors affecting the adoption of fertiliser and intensity of use in Southern Nigeria using five local governments in Akwa Ibom state as a case study. They found a positive relationship of adoption with farm size, output value, and receiving extension services. They also found negative relationships with the price of fertilisers, years of farming, owning a poultry farm and owning domestic animals.

Alabi et al. (2014) used a probit model to investigate the factors affecting agrochemicals' use by smallholder farmers in the Kuje – Gwagalada area in FCT Abuja, Nigeria's capital situated in the North Central zone of the country. They found that the farmer's age, farm size, farmer’s education level, agricultural extension, and family size as a proxy for labour availability positively affect agrochemicals' adoption. They also found that access to credit and off-farm income were negatively related to the adoption of agrochemicals. They explained that this is due to farmers taking credit and investing more in other business endeavours that are more profitable than agriculture.

Uduji & Okolo-Obasi (2018) reported that the farmers’ marital status, distance to an input redemption centre, farming experience, and respondents' age negatively influence the adoption of improved crop varieties in Nigeria. Factors that had positive relationships were sources of getting improved seed, access to credit, off-farm income, household size, level of education and membership in a cooperative body.

From the reviewed literature, we learn that the following socioeconomic factors significantly affect input use: Farmer's perception of inputs effect, farm size, household size as a proxy for labour, access to credit, price of input and output, distance to input markets, off-farm income, receiving extension services, and level of education. The direction of the relationship might be peculiar to the types of input for some of these factors. However, some of the socioeconomic factors are consistent across types of inputs and location, e.g., access to credit, the cost of input acquisition, and inadequate supply of inputs. These factors are directly related to the ability to purchase these inputs, and therefore the following subchapter delves into how Nigerian farmers are financing inputs purchase, with a focus on credit access and credit acquisition.

2.4 How do Nigeria farmers finance the purchase of inputs?

It has been established that the increase in the use of agricultural inputs will lead to increased production. The level of input use in Nigeria has also been presented above. Sheahan & Barrett (2014) showed that Nigerian farmers use these inputs more than was initially reported, especially for fertilisers. Since there is also a consensus that the majority of Nigerian farmers are poor rural farmers, this leads to the question of how they finance the purchase of inputs. Is it through credits or own cash? It is premised that the farmers' situation hinders their ability to save and invest, making credit source of financing inputs an important one for agricultural development in Nigeria (Osabohien et al., 2020).

Recently, Adjognon et al. (2017), motivated by the findings that African farmers use more inputs than was thought initially, looked into this question using four Sub Saharan African countries, including Nigeria, as a case study. They hypothesized from literature that farmers rarely use bank credits to purchase inputs. Farmers mostly use informal credit sources from input and output traders through advances and credit from family and friends. Lastly, farmers partaking in cash crop contracts can get inputs from the processors. They utilized the LSMS-ISA data set with about 5000 households for Nigeria. They found that only 3% of the 71% of surveyed Nigerian farmers that purchased external inputs (fertilisers, improved seeds, and pesticides) used credit. Interestingly, the use of input credit was not dependent on farm size. They reported that most of the farms that used credit for input purchased were under one hectare. There was also no difference between input use for traditional cash crops (cocoa, cotton, tea, and tobacco) and food crops. Tied output and input credit was not common but using output to pay for labour received on credit happened in 26% of households surveyed in Nigeria. They also stated that credit in general without information on the connected use was much higher, with 38% of the households receiving credit from formal and informal sources.

Furthermore, Adjognon et al. (2017) reported that having access to loans relates positively to inputs' purchase. However, a closer look shows that majority of these loans are from family members and not from the formal or semiformal sector. This report confirms that Nigerian farmers lack access to credit facilities, especially formal credits. Adjognon et al. also reported that income from non-farm employment has a positive effect. They concluded that farmers take credit for non-farm businesses and then use the income from these businesses to purchase inputs. They recommended further analysis into the reason for this and the credit accessibility considering interest rates and local (farm level or regional) profitability of inputs used. Interestingly, there were differences between the Northern and Southern part of the country. They explained that this could be due to the North using more inputs and thereby being more responsive to the factors affecting input purchase.

2.5 Nigeria agricultural policies on inputs and credit from 2007-2016

In this subchapter, Nigerian national agricultural policies from three years before the first wave of the data set utilized till the last wave, i.e., from 2007 – 2016, will be reviewed. The review focuses on policies that have direct implications on input use and agricultural finance. The Nigerian government approach towards agricultural sector policies has majorly been through various schemes, programmes, and institutions. Some of these have been in existence since the 70's, thereby sometimes creating an overlap between schemes. In assessing the interventions targeting agriculture financing, Eze et al. (2010) presented a detailed review up to 2010.

- Agricultural credit guarantee scheme fund (1978 – present): This scheme was created to fund small loans, with a 75% guarantee backed by the Central Bank of Nigeria (CBN). The loans are offered at the market interest rate, and for duly repaid loans, the CBN offers a 40% rebate on the loan interest. Eze et al. (2010) reported that this scheme suffered from too much bureaucracy and bottleneck, and at the time of their review, there were already thousands of backlogs dating as far back as 25 years due to the long processing time.
- Refinancing and rediscounting facility (RRF) (2002 – present): This was an incentive targeted to banks that lend long-term to the agricultural sector. They are granted discounted refinancing by the CBN up to a percentage of the long-term agricultural debt on their portfolio when in need of liquidity during the discount window.
- Agricultural credit support scheme (2006 – present): This is targeted towards providing loans to farmers at a lower interest rate. The scheme was capitalized partly by the CBN and deposits from commercial banks. The interest rate is 14%, with CBN taking responsibility for 6%, and the agricultural entrepreneurs or businesses are responsible for 8% at full repayment.
- Large agricultural credit scheme (2009): This was specifically targeted to large and medium scale integrated commercial farms. Large farms were farms with an asset base worth at least 350 million naira and medium with an asset base worth at least 200 million naira.

Under this scheme, the loans are granted with favourable terms such as long tenor and single-digit interest rates.

- There were also programmes such as the National poverty eradication programme (1999 – present): Created by the federal government to provide subsidized credit to farmers, among other things in the four schemes under the program's umbrella.
- A Microfinance policy in 2005 sets out the guidelines for microfinance operation in Nigeria, which majorly involved the provision of financial services to people who would otherwise not have access to one.
- For institutional organizations, the federal government and Nigeria's central bank created the Nigerian Agricultural, Cooperative and Rural Development Bank (NACRDB) in 1972. However, it officially became one institution in 2002 by merging the family economic advancement program, national agricultural cooperative bank, and the people´s bank of Nigeria. The goal is to provide credit to cooperatives, agribusiness, and individual smallholder farmers at a subsidized rate. Although it was reported that even though they now receive deposit today, it has not lived up to its expectation due to poor government funding as the initially declared capitalization has not been completely provided (Eze et al., 2010).

From the myriads of interventions that different administrations have made, it is apparent that the government recognizes the positive impact of agricultural finance on economic growth in Nigeria (Enoma, 2010). Interestingly, credit for agriculture has remained low. Eze et al. (2010) presented challenges faced by these interventions in achieving the set goals. They mentioned that the inconsistency, lack of continuity, insider abuse, elite and political capture are reasons for the policies' failures. They also stated that the lack of adequate know-how in the delivery of agricultural services and small-scale farmers' low management capacity hinders credit acquisition. In addition, most commercial banks are not willing to lend to the agricultural sector due to the higher risk exposure compared to other sector and the low productivity. The weak institutional support especially judicial support also affects private sector participation. Furthermore, most of the policies involve the governments funding and this is barely enough to meet the demands. There is also poor funding from the government for example the NACRDB as of 2010 had only received 23 billion naira out of the fifty-billion-naira capital allocated for them. Majority of the interventions also focus on short term loans, only the RRF focused on long term loans that might suit perennial cash crops. Lastly, the bureaucracy involved in accessing many of these interventions stack the cards against small holder farmers.

Finally, in 2011 as part of the main programmes of the Agricultural Transformation Agenda (ATA), the Nigeria Incentive Based Risk-Sharing System for Agricultural Lending (NIRSAL) was created in a bid to de-risk lending to the agricultural sector. The NIRSAL backed by the CBN provides insurance services to farmers, thereby guaranteeing the credit sector.

Now that we have a brief overview of the interventions affecting credit, the subsequent paragraphs reviews policies affecting the inputs discussed in this chapter.

The governments have introduced policies to promote agricultural inputs in Nigeria (most especially for fertilisers). Many of the interventions are in the form of subsidies. In these regards, there were two different subsidies program between 2007 and 2016. The fertiliser market stabilization program (FMSP) from the 1970s till 2011, and the growth enhancement support (GES) that was under the agricultural transformation agenda (ATA) (2011-2016). As seen in Takeshima & Liverpool-Tasie (2015), during the FMSP period, the federal government purchased fertilisers and then sold them to the state government with a 25% subsidy. The state government then sold to the local governments or distributed through the state-level institution named the agricultural development program (ADP). The state government and the local government also apply their subsidies before selling to the farmers, typically about 75% subsidized. The idea was that majority of the fertiliser required by farmers in the country would be provided by the government. In reality, Takeshima & Liverpool-Tasie (2015) found that the number of farmers who could purchase fertilisers was meagre. They reported no considerable difference in output and local food prices between farmers who bought subsidized fertilisers and those that did not. Akramov (2009) also draws attention to the source of inputs purchase, showing that most Nigerian farmers purchase inputs in the open market instead of government vendors. This report might explain why the subsidies implemented has not had significant effects. However, more farmers used fertiliser in the North than in the South because of a previous targeted fertiliser campaign due to the low fertility level and desertification in the North. They mentioned that anecdotal evidence implied that the subsidized fertilisers in the FMSP leaked to the private sector as the private sector was still involved in fertiliser sales, and the subsidized fertilisers were sold to farmers at commercial rate. Additionally, they mentioned that the subsidies were also affected by elite and political capture.

For the GES, also known as the e-wallet scheme, the government scaled up the use of electronic vouchers for farmers with mobile phones to the national level to correct some of the failures of the FMSP. So, the private sector was charged with purchasing and distributing inputs (fertilisers, improved seeds, and agrochemicals), while the government delivered the different subsidies directly to the farmers through their mobile phones. According to Amurtiya et al. (2018), the subsidy is provided by the federal and state government, and farmers are eligible based on socioeconomic status, age (18 and above), farm size (3 hectares or less), and owning a cell phone with a registered sim card. The government also selected the private sector participants. They were offered deals that allow them to take guaranteed credit from commercial banks. Fertilisers and agrochemicals were subsidized up to 50%, while seeds of selected crops (e.g. rice, sorghum, maize etc.) were subsidized at 75%. Amurtiya et al. (2018) reviewed reports of the program's early impact across the country's different administrative zones. In general, it was very positive with regards to the number of farmers that was able to benefit from the scheme, the increase in output, job creation and farmers attitude towards the scheme. Notably, the attitude of farmers at Ijebu east local government in Ogun state was reported to be negative (Oyediran et al., 2015). However, in a different area in the state, a positive attitude towards the scheme was reported (Fadairo et al., 2015). This scheme is not without its challenges, especially when reviewed in totality, putting the later years into consideration. Amurtiya et al. (2018) delved into the myriad of challenges hindering the GES from achieving its full potential. They mentioned the following:

- Elite and political capture.
- Huge pressure on government expenditure (leading to government owing agro-dealers).
- Inadequate extension and information services.
- Sub-standard or fake inputs.
- Inputs unfit for location.
- Delay in delivery and processing of inputs and vouchers.
- Communication infrastructural limitations that automatically excludes farmers in more remote rural communities.
- Consistency in the scheme's availability (only a few states had the program running for the year as of August 2016).
- High transaction cost to participate.
- Discordance and distrust between stakeholders; some states pulled out of the program due to issues regarding federal governments handling and influence on the scheme.
- Due to the federal government selecting the dealers, it created monopolies in some regions, which affected farmers trust in the program.
- Lastly, the quantity of inputs being distributed was considered too small to meet the farmers' needs.

The last challenge probably drove farmers to purchase inputs without vouchers because the percentage of beneficiaries when the LSMS data set was analysed was meagre. It is important to note that there were policies and incentives to incentivize these inputs' local production, but they are not mentioned here due to this paper´s focus on the demand side.

2.6 Summary

From the literature reviewed above, we can see that even though the benefits of using modern agricultural inputs are well known, Nigeria's usage still has lots of room for improvement, especially with other inputs apart from fertiliser. Papers that delved into the intensity of fertiliser use also stated that the usage is not at the optimum level yet. Nonetheless, the most recent usage data showed that current levels are higher than what was initially reported in literature before the LSMS data set became available. We also see that complementary use is low, even though the benefits of the synergistic use of inputs are generally higher than the individual use of inputs. We took a run through the factors that affect the adoption / or use of inputs and the level of input use in Nigeria. Like in most Sub Saharan African countries, socioeconomic characteristics and agroecological characteristics are the main factors. Factors such as age, level of education, access to credit, price of inputs and outputs, types of crops planted affect Nigeria's input use. Due to this research's scope, the Adjognon et al. (2017) paper was the main focus as it provides recent insights on the financing of agricultural inputs in Nigeria, especially regarding credit. We see that agricultural credits are still low despite the myriad of government interventions, schemes, and programs, although credit that is untied to agriculture is considerable. Farmers finance inputs purchase with income from non-farm enterprises.

Lastly, we reviewed the two inputs subsidy programs that existed in Nigeria during our focus period. The FMSP was mostly ineffective due to the reasons detailed in the review. The GES had positive results in the early days but became ineffective as time went on due to some of the reasons that also plagued the FMSP, such as political and elite capture, and some of its unique problems such as fake inputs, distrust between stakeholders and more. We use the LSMS data set to investigate the effect of receiving credit on individual and complementary inputs use in Nigeria for fertilisers, herbicides, pesticides, and purchased seeds.

3. Data and Methodology

3.1 Data

For this research, quantitative secondary data was used to carry out descriptive panel statistics and panel regression analysis in order to answer the research questions.

Three waves of the General Household Survey panel (GHS) data set collected by the National Bureau of Statistics (NBS) in collaboration with the World Bank´s Living Standard Measurement Survey (LSMS) were utilized. The GHS panel in sampled approximately 5000 households from the GHS cross-sectional study covering 22,000 households. The panel data was collected with the focus of linking agricultural data to household and community characteristics. The data set contains plot level, household level, community level, and ancillary geo-referenced data. The survey covered all 36 states of Nigeria, including the FCT, using a two-stage sampling technique to select households. The first wave covered 4916 households, and it was collected between 2010-2011 (post-planting and post-harvest period), the second wave covered 4,851 households between 2012-2013 (post-planting and post-harvest period), and the third wave covered 4,581 households between 2015 -2016 (post-planting and post-harvest period). The second wave and third wave of the data set had fewer respondents due to respondents who moved and were untraceable. Only households that carried out cropping activities were included in the analysis. Missing values on inputs use (dummy) also led to removing the household to avoid imputations.

Therefore, for research question 1, wave 1 included 5905 plots and 3089 households, wave 2 included 5802 plots and 2977 households, wave 3 included 5721 plots and 2869 households. For research question 2, only households involved in cropping activities and present in all waves of the data set were used. Households with missing values in any of the relevant input variables were dropped to avoid imputations as the missing values were small, after considering missing values due to answering “No” to a previously relevant question, e.g., whether the land was cultivated for the planting season or not. Additionally, the data set is still considerably sized after dropping the observations with incomplete data. Therefore, the statistics included 2425 households all over the country.

3.2 Data Analysis

In answering the first and second research question, descriptive statistics were analysed on both household and plot level. However, the reporting was carried out to suit the operational definitions of complementary and consistency, as defined in chapter 1.

- Consistency: This implies the continuous application or use of these inputs by households in every wave of the data analysed.
- Complementary: This represents the use of more than one input on a single plot and more than one input by a household.

For complementary use, statistics were mainly reported on the plot level, and consistency of use statistics was mainly reported on the household level. Household-level and plot-level statistics only had minor differences. The survey weights have not been used in any of the analysis, so the results are sample statistics and not generalizable nationally. The inputs that were considered are inorganic fertilisers, herbicides, pesticides, purchased seeds, and irrigation.

For the third research question, the following variables were used in the regression:

- Dependent variables: dfertiliser, dherbicide, dpesticide, dseedpurch, and complementary.
- Independent variables: waves, sector, hhheadage, hhheadgender, hhheadedu (years of education), disttomarket (km), annualtemp×10°c, meanannprec (mm), Plotsize (sqm), dextension, dmachinery, offfarmlabour, dcashcrop, dformalcredit, dinformalcredit, cropincomelog, otherincomelog, nonfarmincomelog, and zones (North Central, North East, North West, South East, South-South, South West).

In the following, the variables are briefly described:

- dfertiliser, dherbicide, dpesticide, and dseedpurch, dmachinery are dummy variables for using inorganic fertilisers, herbicides, pesticides, purchased seeds, and machinery, and it was used as reported in the data set.
- complementary is a bounded continuous variable created from the simple addition of the values of dfertiliser, dherbicide, dpesticide, and dseedpurch, as a representative proxy for household complementary input use.
- sector is a binary variable representing the households situated in rural areas and urban areas.
- hhheadage and hhheadgender represent the age and gender of the household head, respectively, and it was used as presented in the data set.
- hhheadedu represents the household head’s years of education computed from the data set's categorical education variable. There was a little bit of imputation done to ensure the accuracy of the variable conversion, such that the level of education is not lower in more recent waves compared to previous waves. If the education recorded for wave two is lower than wave one, we use wave one for wave two, and if wave two is higher than wave three, we use wave two for wave three.

- disttomarket (kms), annualtemp×10°c, meanannprec (mm), plotsize (sqm) were all used as presented in the data set. They represent the household distance to market in kilometres, annual temperature multiplied by 10 in degrees Celsius, mean annual precipitation in mm, and plot size from Global Positioning System (GPS) data in square meters.
- dextension is a dummy variable where one means yes for households in which any member received extension services on fertilisers, agrochemical, improved seeds, and credit. This variable was generated from the extension variable in the data set.
- offfarmlabour is a dummy variable where one means yes for households in which any member worked on someone else´s farm apart from plots owned by households. This variable was generated from the main and secondary labour variable in the data set.
- dcashcrop is a dummy variable representing households that planted any of the following crops, beans, cotton, groundnut, rice, ginger, soya beans, tea, tobacco, cocoa, coffee, kola nut, oil palm, oil bean, and rubber. We defined cash crops as crops mainly grown to be sold locally or internationally.
- dformalcredit is a dummy variable where one means yes for households in which any member received credit from formal sources such as bank, cooperatives, savings association and microfinance bank.
- dinformalcredit is a dummy variable where one means yes for households in which any member received credit from informal sources such a local contribution groups and other informal savings group.
- cropincomelog is a logarithmic conversion of the continuous variable for all income from crop sales in post-planting and post-harvest.
- otherincomelog is a logarithmic conversion of the continuous variable for income from non-agricultural rentals, investment or savings interest, and other income such as gifts and grants.
- Nonfarmincomelog is a logarithmic conversion of the continuous variable for income from households' non-farm businesses.

3.3 Statistical Models

In analysing the effect of credit on the dependent variables, a random effect logit panel model and random effect Poisson panel model was used. The panel random effect logit models were used because the dependent variables were binary when investigating single inputs. The assumption is that individual-specific unobserved effects are uncorrelated with the regression's explanatory variables (Wooldridge, 2002). Additionally, it allows us to retain a larger sample size and include the zonal variables compared to a fixed-effect model. The zone and wave variables were used as control variables for unobserved effects that might correlate with the households. Similar analysis done by Adjognon et al. (2017) showed that including the time or wave variable controls for possible heterogeneity. However, if these assumptions should fail, the coefficients of the result may be biased. Therefore, the estimates are reported as correlation coefficients rather than causal estimates due to the limitations of ensuring a completely endogenous set of variables. In addition, robust standard errors were used in order to ensure unbiased standard errors. We are also able to estimate the effect of variables that do not change a lot over time, such as hhheadgender, hhheadedu, and meanannprec etc. Although the estimator for the Logit model is not as straightforward compared to the Probit model where the normal distribution facilitates random effect estimation, it does holds an important advantage in the consistency of the estimator β, namely in allowing us to relax our assumptions about how vi is related to xi (Wooldridge, 2002). The panel random effect logit model specification is:

$Pr\ (yit \neq 0|xit) = P\ (xit\beta + vi)$

i stands for the households, and t represents the time factor (wave 1-3)

β represents the estimated effect

y is the binary outcome (0 or 1) for the use of the individual inputs or not

x are the independent variables such as household head gender, formal credit, mean annual precipitation, cash crop, etc. They are a mix of binary and continuous variables

v represents household-specific unobserved effects, and they are i.i.d.

The Poisson panel model was used for the complementary use because the dependent variable is a strictly positive count variable with an upper bound, i.e., $0 \leq y \leq 4$. The Poisson model allows to correctly estimate the independent variables' effect on this type of dependent variables (Wooldridge, 2002).

The model specification is:

$Pr\ (Yit = yit|xit) = F\ (yit,\ xit\beta + vi)$

i stands for the households, and t represents the time factor (wave 1-3)

β represents the estimated effect

Y is the count outcome

Y is the independent outcome conditional on y and v x are the independent variables such as household head gender, formal credit, mean annual precipitation, cash crop, etc. They are a mix of binary and continuous variables

F (x, z) = Pr (X = x), where X is Poisson distributed with mean exp(z)

Vi are i.i.d. unobserved effects that are uncorrelated with xi

Exp (vi) is gamma with a mean of 1 and variance α.

3.4 Software

R and Stata were used for the analysis. R was used for data cleaning and creating the upset plots, while Stata was used for the panel regressions. The use of different software was because the underlying method in R for panel Tobit analysis could not handle the initial variable size, but Stata could.

3.5 Robustness Check

The cash crop considered in the analysis contains more crops than the traditional cash crop considered in Adjognon et al. (2017). The majority of the variables, such as wealth class, other farm income, and soil characteristics, were removed as they were mainly statistically non-significant. Removing the ones with statistically significant coefficient did not have any considerable effect on the model results.

4. Results

4.1 Research Question One – Complementary Input Use

What is the extent of complementary agricultural inputs use in Nigeria from 2010-2016? The descriptive statistics carried out on three rounds of the LSMS data set yielded the following results. The data was collected in the following order: wave one from 2010-2011, wave two from 2012-2013, and wave three from 2015-2016. The results have been presented in upset plots and tables, as seen throughout this chapter. The upset plots show the number of plots or households that used a particular input on the horizontal bar chart on the left. The count of households or farm plots that fit a usage pattern is represented on the vertical bar charts coloured red. The dots and lines show the inputs intersect, indicating the usage pattern. Plots or households that did not use any inputs are not shown on the upset plot, and only intersects that existed in the data were represented on the upset plots.

4.1.1 Wave 1

Fig 3 below shows that 2249 farm plots had fertilisers applied on them, 1552 had purchased seeds planted on them, 1455 had herbicides applied on them, 811 had pesticides applied on them, and 152 farm plots were irrigated. For the main bar charts, we see that 766 plots had only fertiliser applied on them, 690 had purchased seeds planted on them, 474 had only herbicide applied on them, 438 farm plots had only herbicides and fertilisers applied on them, 397 farm plots were planted with purchased seeds and had fertilisers used on them, 120 farm plots had only pesticides, herbicides, and fertiliser applied on them, etc.

Fig. 3 shows that inputs are mostly used individually, with single-use of fertilisers been the most common usage with 13% (766) of farm plots. The most common complementary use of inputs was herbicides and fertilisers; 7.4% (438) of farm plots in the sample had herbicides and fertilisers applied complementarily. Followed by 6.7% (397) of farm plots that had purchased seeds and fertilisers applied. The joint use of fertilisers, herbicides, and pesticides on the same farm plot only accounted for 2% (120), and 29.9% (1764) of farm plots had any of the five inputs applied on them jointly.

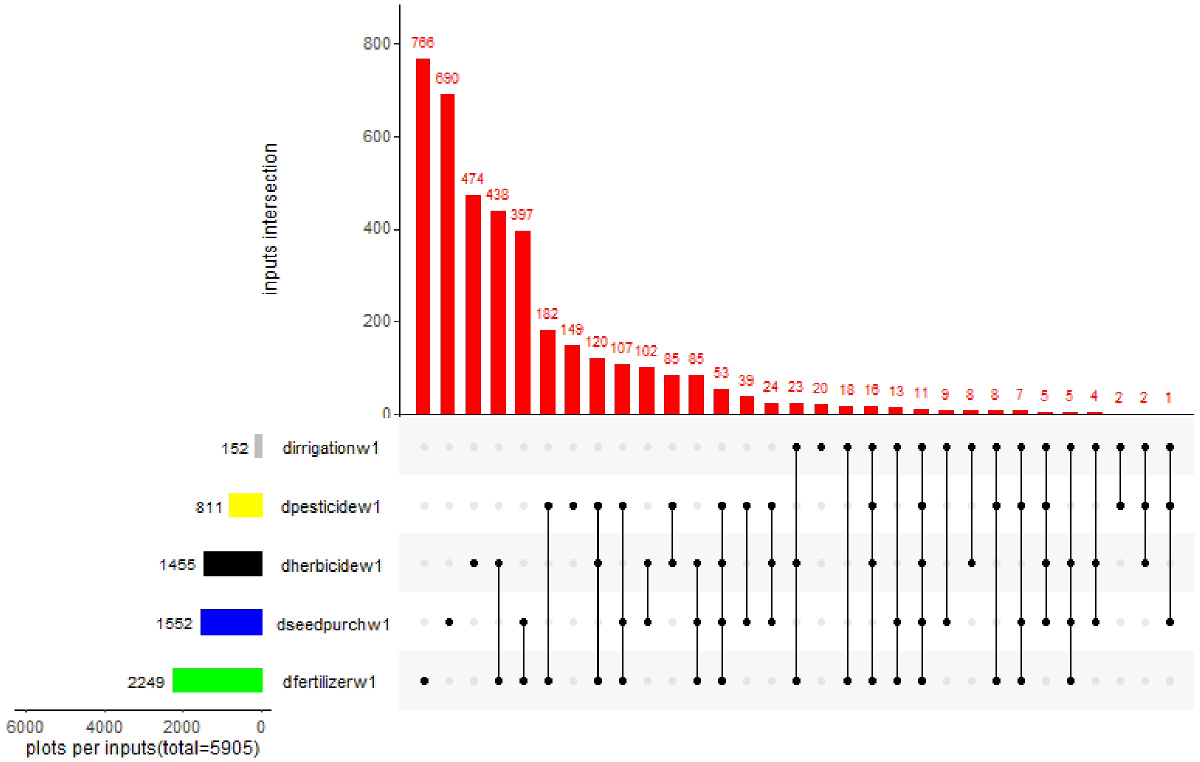

Figure 3. Intersection of inputs use per plot in Nigeria (wave 1)

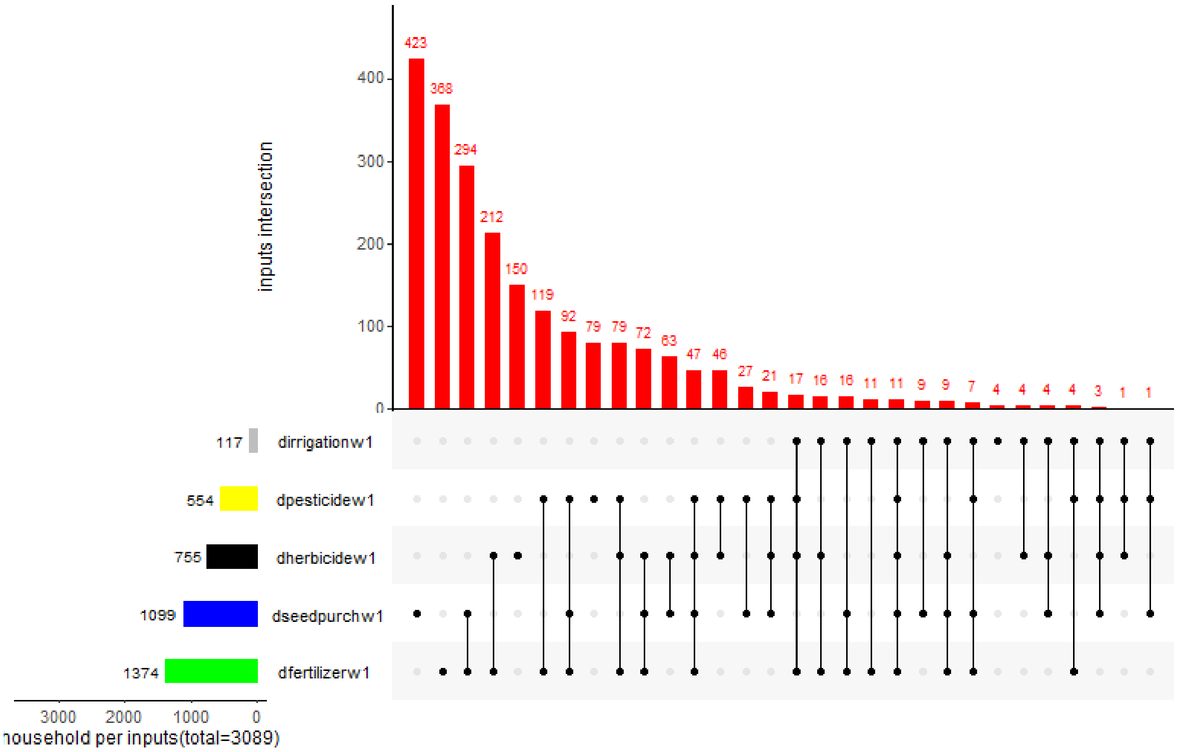

Figure 4. Intersection of inputs use per household in Nigeria (wave 1)

These percentages are not considerably different from the percentages when analysed at the household-level, as shown in Fig 4. The most significant differences between Fig 3 and Fig 4 are that the use of purchased seeds surpassed fertilisers as the most common input use individually on the household level with 13.7% (423) of households and 11.9% (368)

respectively. Also, the percentages of household input use are slightly higher than the farm plot level usage in most cases. Showing that even though more households use inputs, some households apply the inputs on only some of the farm plots they own and not all. For example, 35.6% (1099) of households used purchased seeds, and purchased seeds were planted on only 26.3% (1552) of farm plots. This trend continues with most inputs across all zones. Therefore, this study will continue to focus on only the description of inputs used on the farm plot level. This will allow us to get a more accurate view of the complementary usage of inputs on farm plots.

Further analysis of the zonal variations in the complementary usage of inputs shows more interesting results. There are huge variations between administrative zones in Nigeria; Variations regarding the most common input use, the proportion of plots with inputs applied on them and the most common complementary use of inputs. The most distinctive zonal results will be presented in the figures below from the northern zones to the southern zones. The northern part of the country consisting of the North Central, North East, and North West shows a high application of inputs on farm plots compared to the national proportion, with slight differences seen in Fig 5 and Fig 6. Fertilisers were the most common input used in the North Central, while herbicides were most common in the North East. Complementary use of fertilisers and herbicides were the most common joint use, the same as in the national data set, with 12.4% (151) in the North Central and 14.6% (212) in the North East.

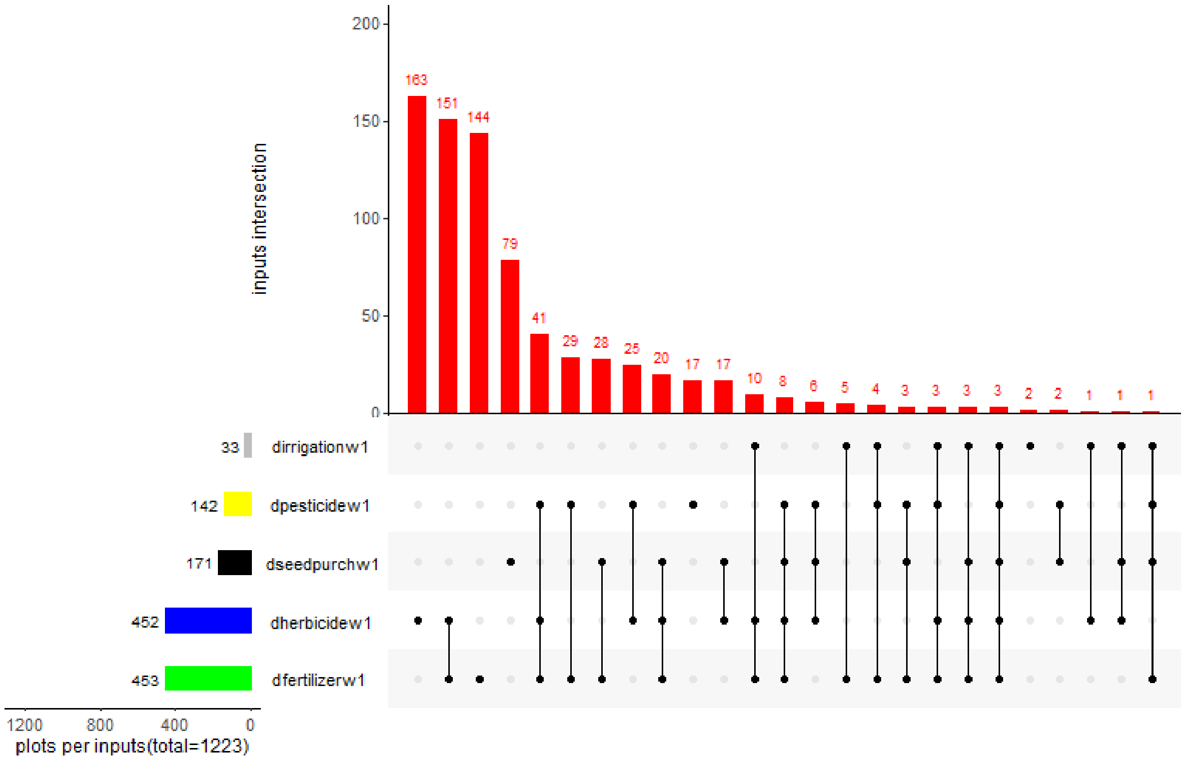

Figure 5. Intersection of inputs use per plot in North Central, Nigeria (wave 1)

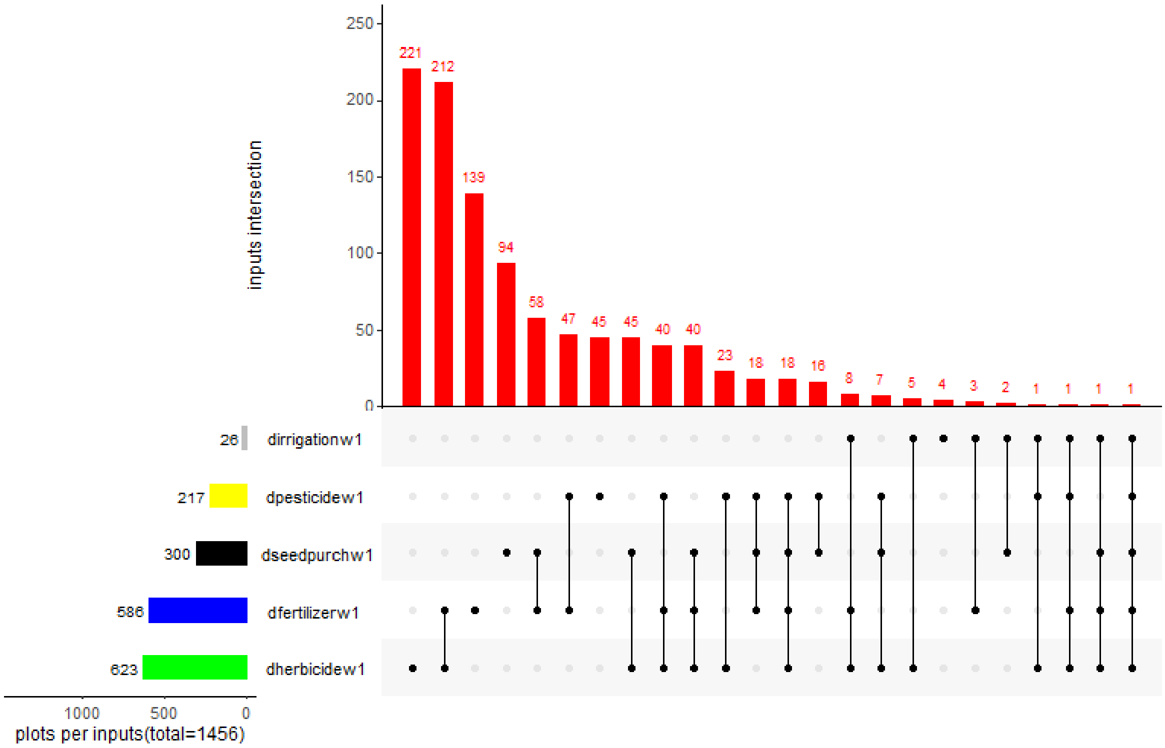

Figure 6. Intersection of inputs use per plot in North East, Nigeria (wave 1)

Fig. 7 shows the inputs use intersect on the farm plot level for the North West. The North West is separately represented because even though it is like its northern counterparts in being the region with most inputs applied, it is considerably different in proportions. Fertiliser usage in the North West is the highest nationally, with 75.5% (689) of farm plots having fertilisers applied. The single-use of fertilisers was the most common usage pattern. The most complementary usage was also different from the national data and the other northern zones. Joint usage of fertilisers and purchased seeds on farm plots was more common, with 12.3% (112) of farm plots having them used simultaneously.

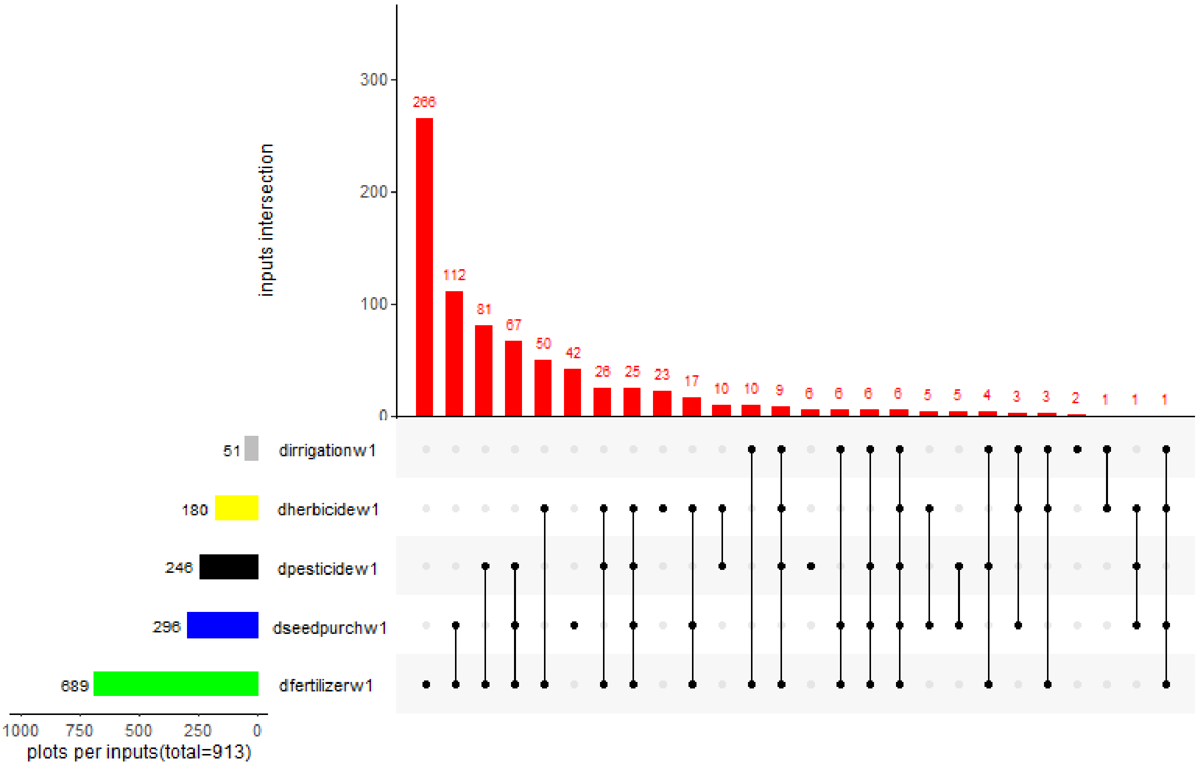

Figure 7. Intersection of inputs use per plot in North West, Nigeria (wave 1)

Moving southward in the country, the zonal differences were more apparent. Inputs use lessened, complementary use was less common, and the use of purchased seeds became more pronounced. Purchased seeds were the most common input used, and their single-use was the most common usage pattern. Fig 8 below shows that the most common complementary use is purchased seeds and fertilisers with 15.3% (166) of plots.

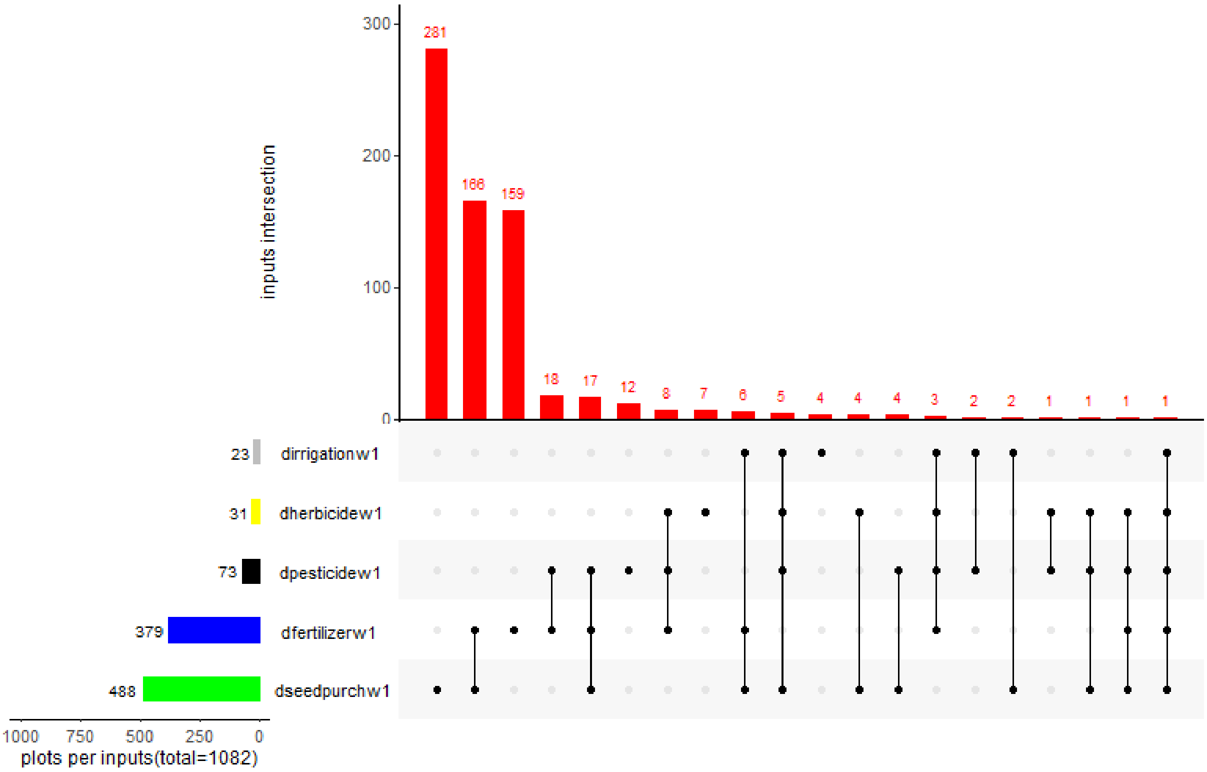

Figure 8. Intersection of inputs use per plot in South East, Nigeria (wave 1)

The general input use was lower in the South-South, and South West. Purchased seeds remained the most common input used, and complementary use is lower than in the North. However, the use of pesticides in the South West was higher than in other southern zones. Fig 9 shows that purchased seeds and pesticides were the most used inputs in the South West with 25% (116) and 24.8% (115) of farm plots, respectively, as opposed to fertilisers in the northern zones and the national dataset. The most common jointly used inputs are herbicides, and pesticides with 5.6% (26) of farm plots on this intersect.

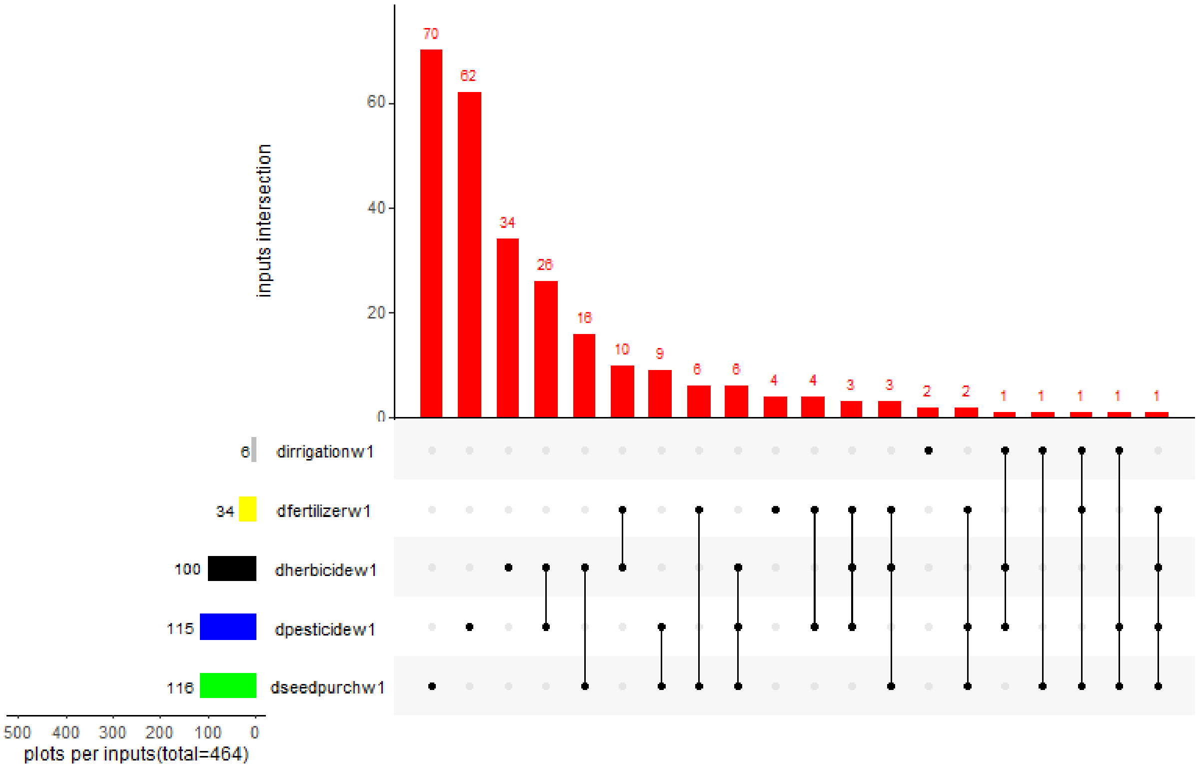

Figure 9. Intersection of inputs use per plot in South West, Nigeria (wave 1)

4.1.2 Wave 2

The following figures and descriptions show the upset plot for farm plots in Nigeria LSMS wave 2 data set. Fig 10 shows the proportion of inputs used individually and complementarily on plots in Nigeria. Just as in wave one, fertilisers remained the most common input applied on plots. Use of purchased seeds dropped nationally while others stayed similar proportion-wise. The most common joint use of inputs on plots was still herbicides and fertilisers at a slightly higher proportion than previous years at 8.1% (469). Individual use of fertilisers remained the most common inputs applied on plots. About 28.4% (1645) of farm plots had any of the five inputs applied complementarily. The household-level analysis showed similar proportions and usage patterns as the plot level analysis again. This result follows the same trend as in wave one.

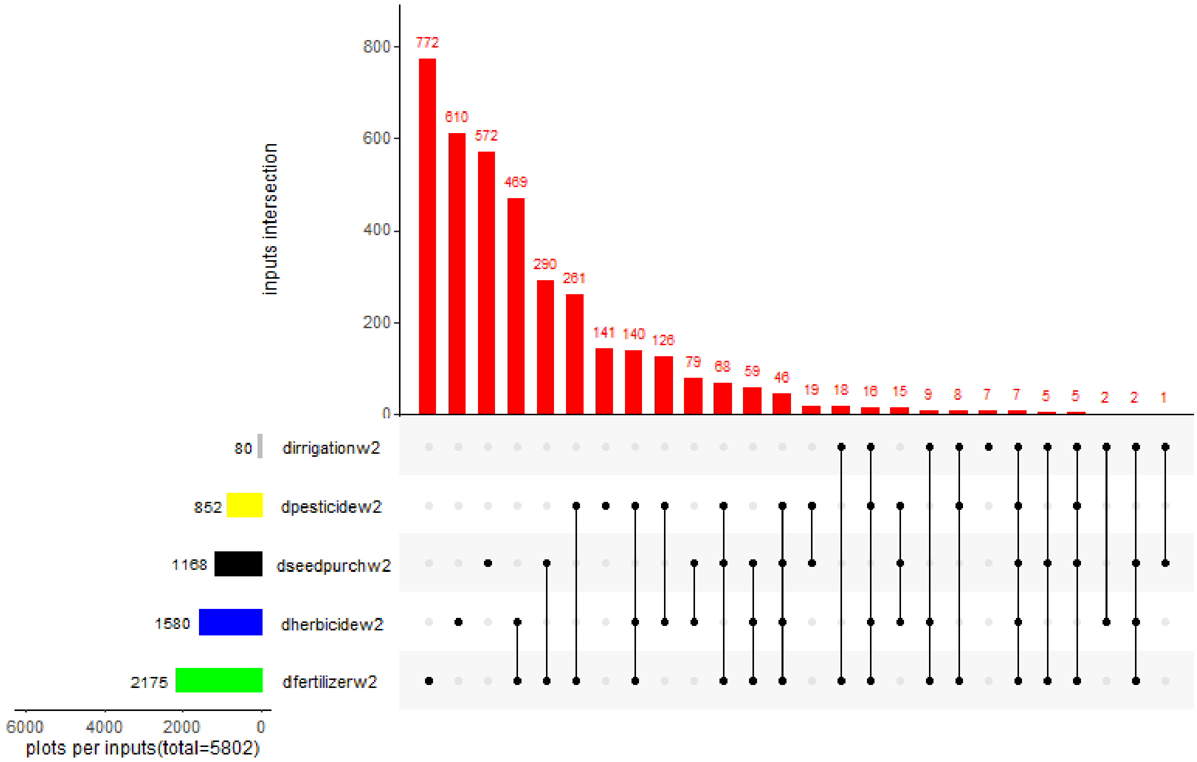

Figure 10. Intersection of inputs use per plot in Nigeria (wave 2)

The similarity in usage pattern between wave one and wave two continued as there are also substantial zonal differences in the usage pattern. Fig 11 shows that the most common input used in the North Central are herbicides as opposed to fertilisers in wave one. In wave two, 50.3% (538) of farm plots in the North Central had herbicides applied on them, from 37% in wave one. The individual application of herbicides was the most common usage pattern on 25% (267) of farm plots. The most common joint application remained herbicides and fertilisers on 12% (128) of farm plots.

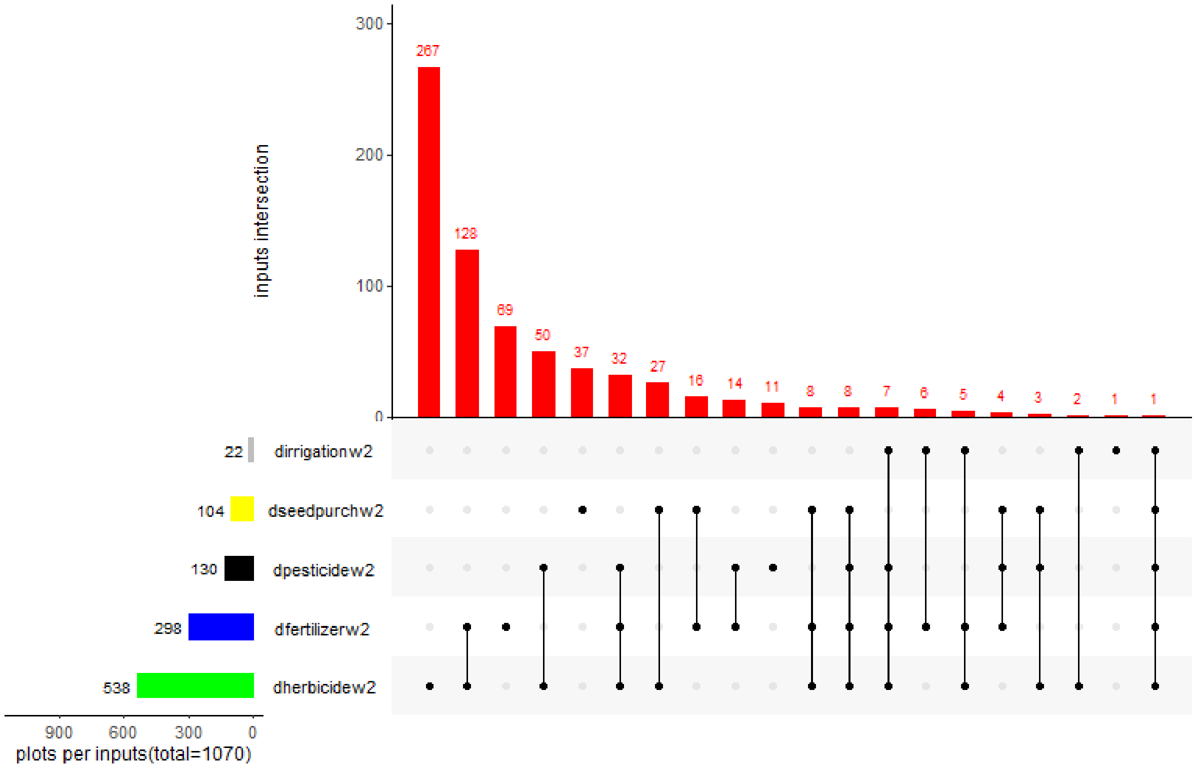

Figure 11. Intersection of inputs use per plot in North Central, Nigeria (wave 2)

The complementary usage pattern in the North-East remained similar with slight differences in proportion when compared to wave 1. The trend continued with the comparison of zones and the national level analysis in wave 2. The northern part of Nigeria applied more inputs on plots in general (individually and complementarily). Fig 12 below shows that the North West continued to lead with the usage of fertilisers. A higher proportion of farm plots had fertilisers applied on them compared to wave one, with 80.7% (897) of plots. The most common complementary use of inputs was applying pesticides and fertilisers on plots, differing from the other northern zones, with 14.9% (166) of farm plots intersecting on these inputs. The complementary use of fertilisers and purchased seeds, herbicides, and fertilisers also improved with a proportion of 13.1% (145) and 9% (100). In the North West, 56.7% (630) of plots were applied with any of the five inputs jointly in different patterns.

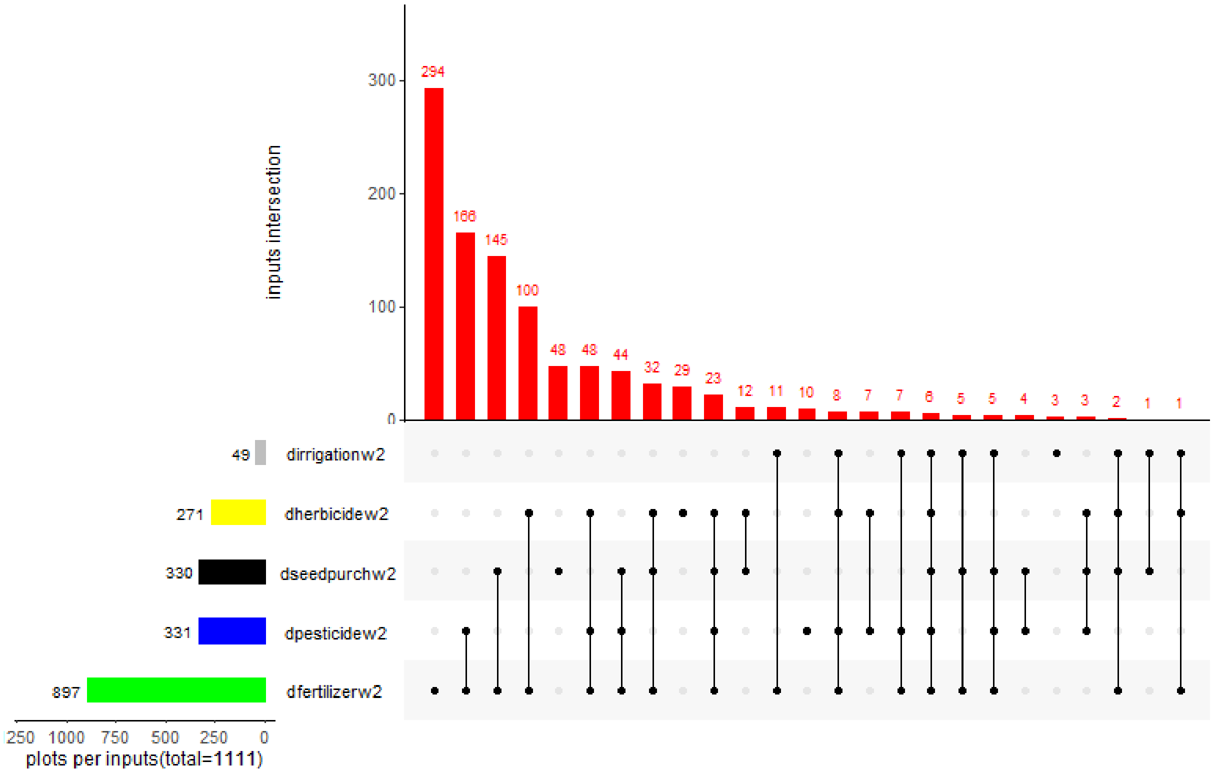

Figure 12. Intersection of inputs use per plot in North West, Nigeria (wave 2).

Fig 13 below shows that individual use remained the most common usage pattern for inputs in the South East. The most common complementary use was the use of purchased seeds and fertilisers with a proportion of 10.5% (112) of farm plots. Compared to wave one, inputs-use remained relatively the same in the South East for single use and complementary use.

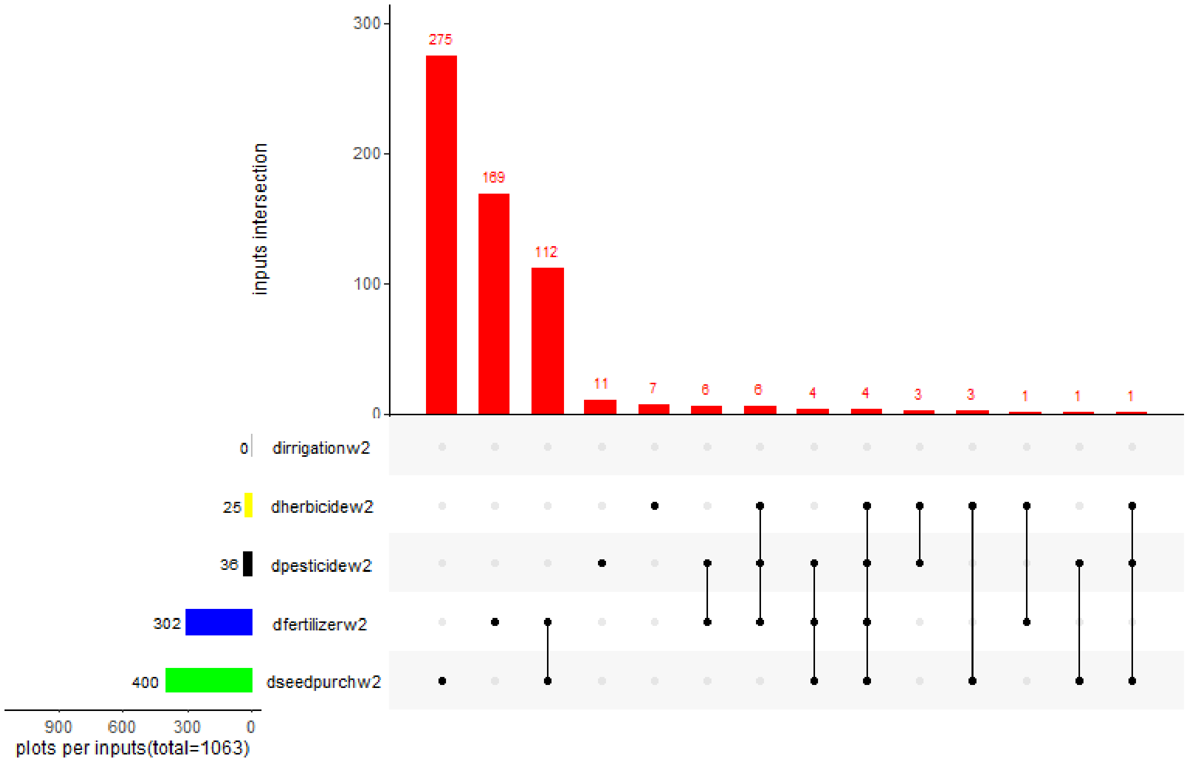

Figure 13. Intersection of inputs use per plot for South East, Nigeria (wave 2)

In the South-South, there was a slight reduction in complementary use and single use. Although the ranking of inputs used remained the same. Fig 14 shows that the South West saw a change in inputs use. The application of pesticides and herbicides increased, while the use of purchased seeds reduced compared to the first wave. Single application of pesticides was the most common application pattern. The Joint use of pesticides and herbicides increased, and it also remained the most common complementary usage pattern with 11% (50) of the farm plots intersecting on these inputs.

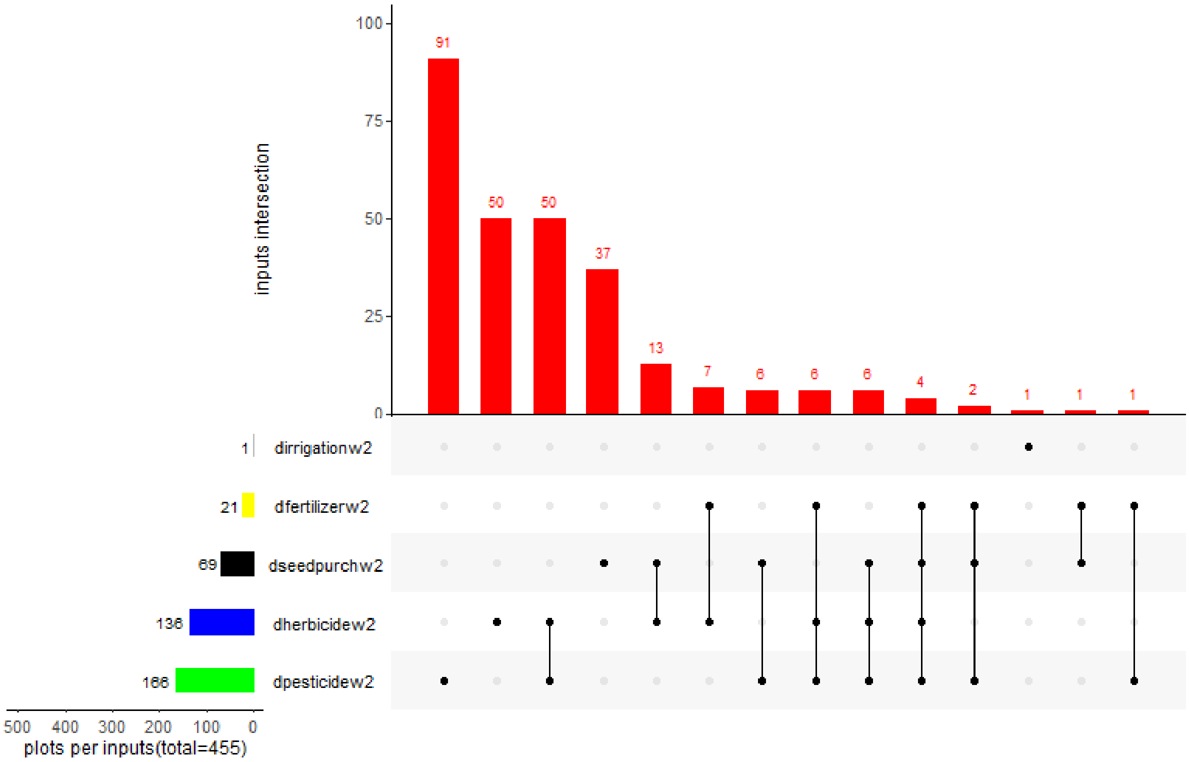

Figure 14. Intersection of inputs use per plot in South West, Nigeria (wave 2)

4.1.3 Wave 3

The following figures and descriptions show the upset plot for farm plots in Nigeria LSMS wave 3 data set. Fig 15 shows the input application pattern on plots in Nigeria. In comparison to the previous waves discussed, the ranking of inputs in plot proportions remained similar. Single-use of fertilisers and herbicides remained the most common inputs usage pattern on plots. The most common complementary use is still herbicides and fertilisers at 8.5% (467). 33.5% (1917) of farm plots had any of the five inputs applied complementarily. There are similarities in the zonal inputs' usage as in the previous waves.

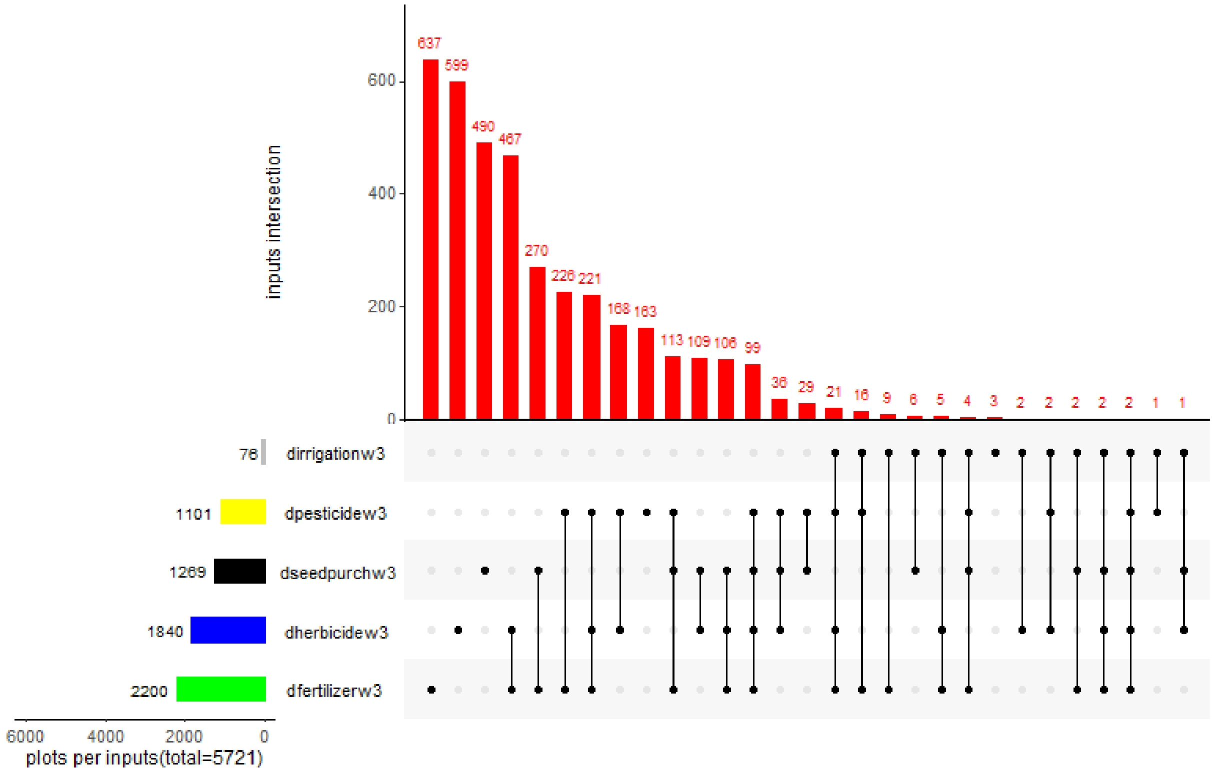

Figure 15. Intersection of inputs use per plot in Nigeria (wave 3)

Farm plots in the northern part of the country remained the highest beneficiaries of inputs individually and complementarily in the country, with similar differences within the north, as seen in previous waves. Fig 16 shows the usage pattern in the Northwestern zone of Nigeria. The use of fertilisers reduced to 73% (855) of the farm plots compared to wave two. The application of pesticides increased to 45.9% (538) compared to wave two. Complementary use remained like previous waves with slight differences; only fertilisers, pesticides, and herbicides on the same farm plot was recorded for 8.5% (99) of the farm plots, higher than wave two and slightly higher than wave one.

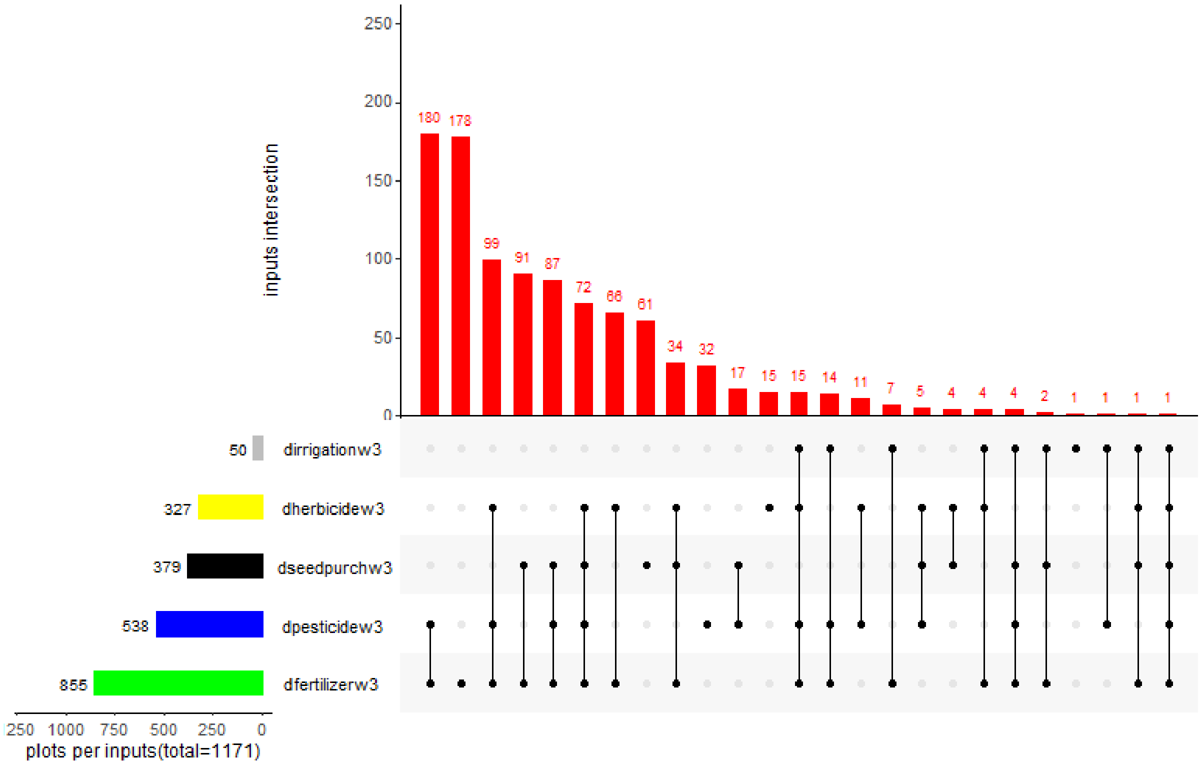

Figure 16. Intersection of inputs use per plot in North West, Nigeria (wave 3).

In the southern part of the country, the similarities with the previous waves continued. There was lesser use of inputs individually and jointly on plots. Although zones across the waves, inputs used in the southern zones in wave 3 was more than the previous waves. There were changes in the order of inputs used as well. Fig 17 shows that the South East had fertilisers applied on 40.1% (408) of its farm plots. The use of purchased seeds also occurred on 39.1% (398) of the farm plots. The complementary use of purchased seeds and fertilisers increased to 15% (152) of farm plots, compared to wave 2. A much higher 22% (224) of the plots had any of the inputs applied complementarily compared to 13.3% in wave 2.

In the South-South, the most common input used remained the same (purchased seeds), but the use of herbicides increased. Herbicides were applied on 16.9% of farm plots surpassing fertilisers. The South-West did not show any significant deviation from the usage pattern in the previous years. However, usage proportion increased for the number of farm plots with the five inputs applied on them and the complementary usage of herbicides and pesticides.

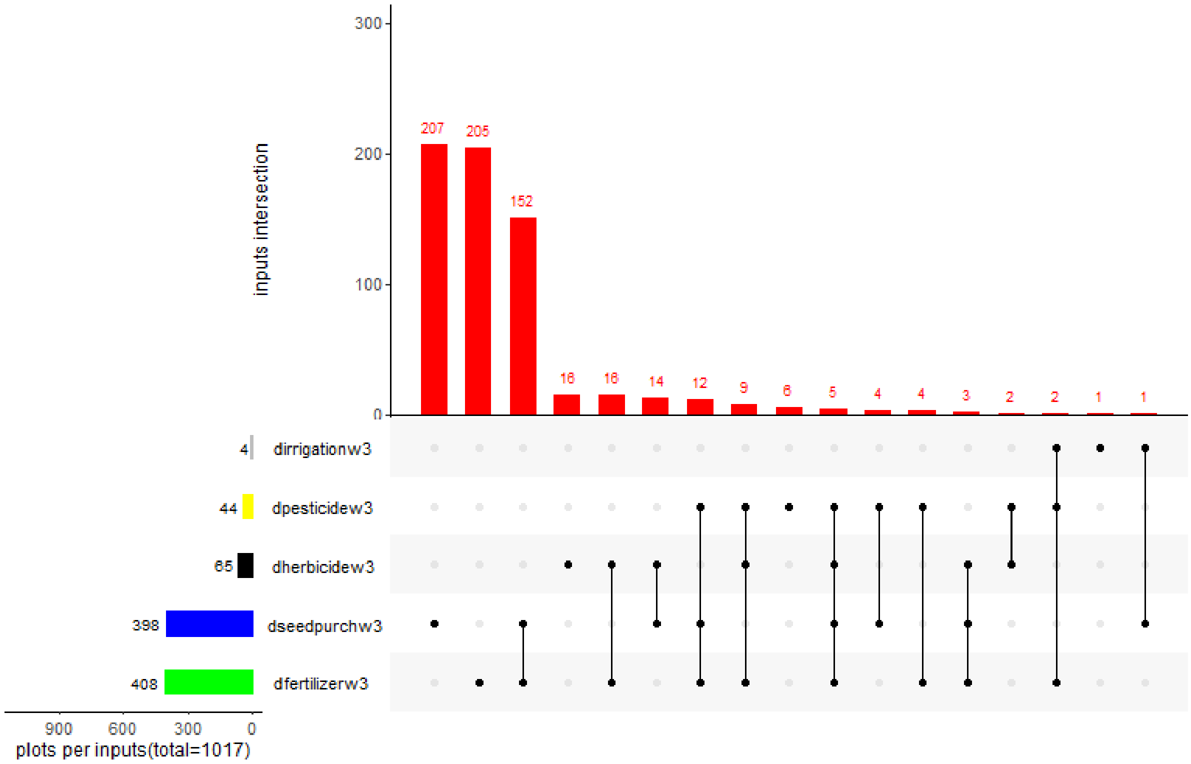

Figure 17. Intersection of inputs use per plot in South East, Nigeria (wave 3).

4.2 Research Question Two – Consistency of Input Use

How consistent are Nigerian farmers' inputs use (analyzing data from 2010-2016)? The figures below show the descriptive statistics on household consistency in using modern agricultural inputs in Nigeria. Only the household analysis is presented here because the differences between household and farm plot-level analysis are not considerable. It provides more insight to consider the results of consistency from the household level. Households analysed here are only households present in all three waves of data for this descriptive analysis. This way, our operational definition of consistency remains intact. National household level and unique zonal household-level results on the consistency of inputs such as fertilisers, pesticides, herbicides, purchased seeds, and irrigated are presented in this subsection. Tables showing the trend of inputs use nationally and zonally are presented at the beginning of the subsection introducing a new input.

4.2.1 Fertilisers

Table 1 shows that the North West households used fertilisers more than any other zones and considerably more than the national value with 77.7%, 83.3%, and 71.5% of household in the region using fertiliser from the first wave to the third wave, respectively. Less household in the South West used fertilisers.

Zones	Wave 1 (%)	Wave 2 (%)	Wave 3 (%)
Nigeria	47.9	46.6	45.3
North Central	47.3	37	44.6
North East	51.8	57.5	47.5
North West	77.7	83.3	71.5
South East	38.2	30.4	43.1
South-South	18.3	18	11.7
South West	10	5.9	8.2

Table 1. Household fertiliser use in Nigeria and administrative zones (wave 1-3)

In fig 18, the bar chart for the household counts for fertiliser use in each wave is shown on the left as a horizontal bar chart. The vertical bar chart shows the counts for intersecting households. The intersects can be seen in the dots and lines below the vertical bar chart. Fig 18 below shows that 26.4% (641) of farming households in Nigeria used fertilisers consistently between the years analysed. About 20% (486) of households used fertiliser only once, while 46.6% (1131) of households applied fertilisers at least twice in the three waves of data used.

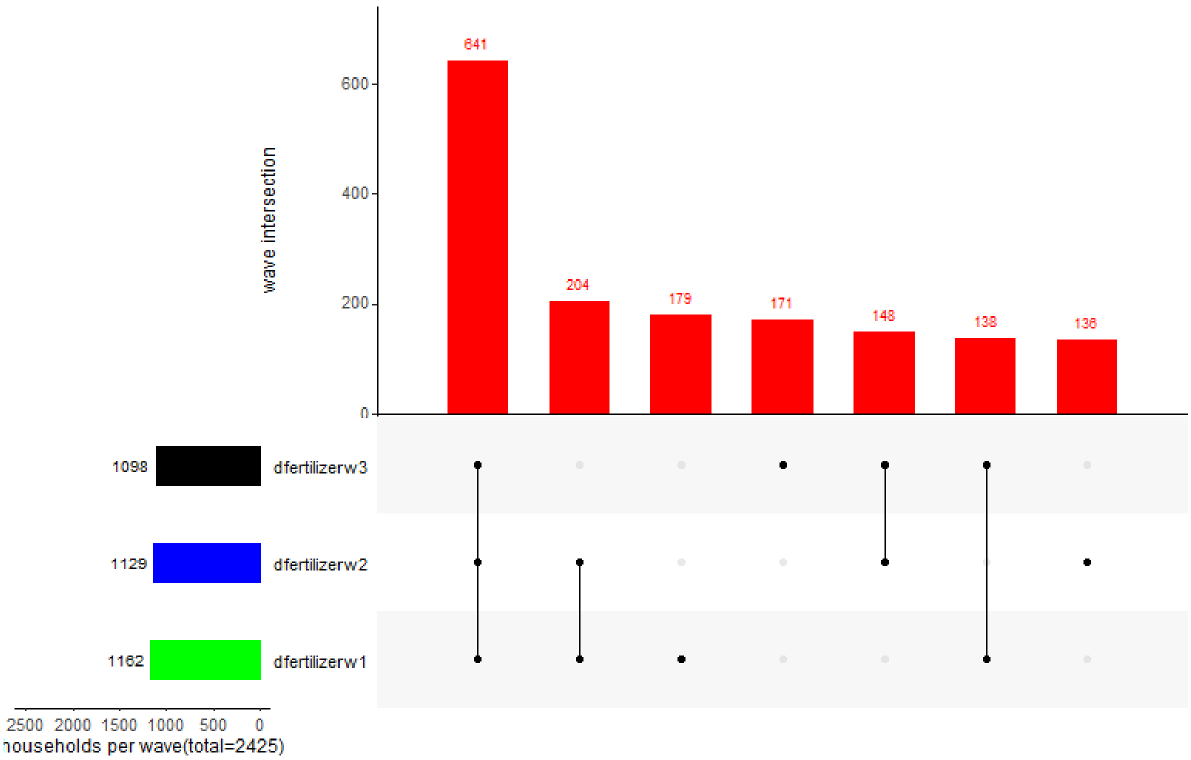

Figure 18. Household consistency of fertilisers use in Nigeria (wave 1-3)

Fertiliser usage consistency also varied between administrative zones, just like with the complementary use above. Northern households were more consistent than Southern households in using fertilisers. Fig 19 shows the most consistent zone for household use of fertilisers in Nigeria, the North West. About 55% (332) of households used fertilisers in the three waves of data analysed, and 82.6% (499) of households used fertilisers at least twice in the three rounds of data analysed.

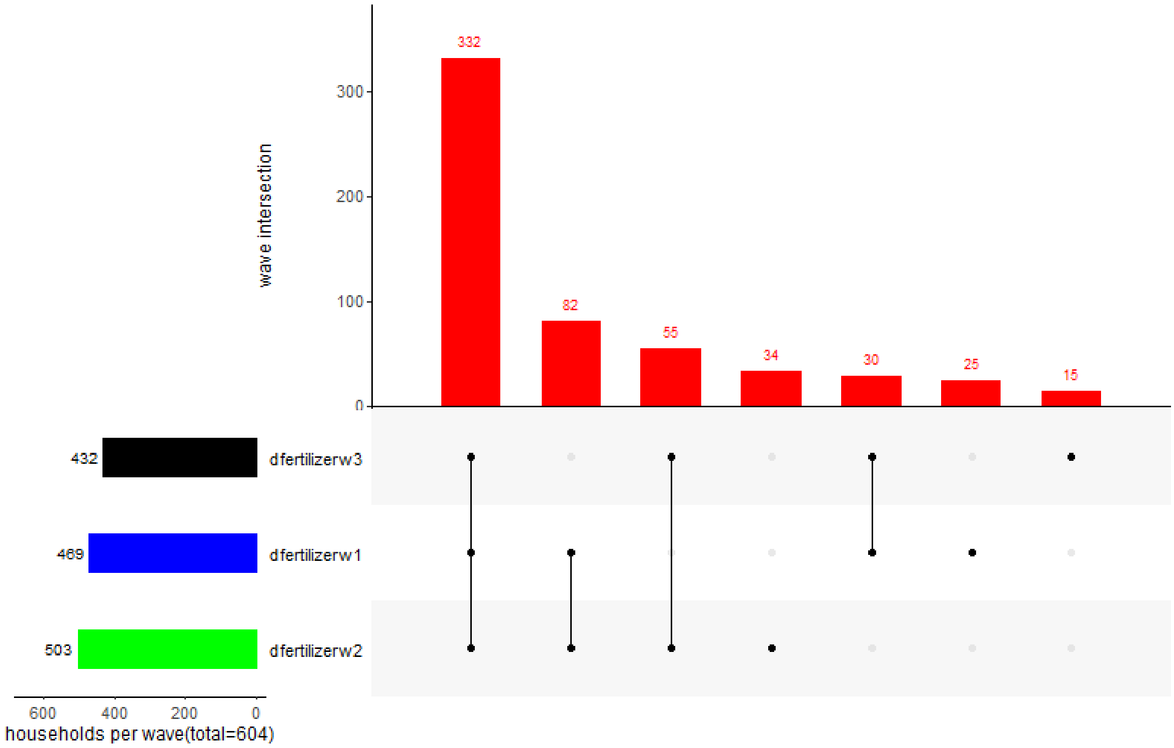

Figure 19. Consistency of fertilisers usage in North West, Nigeria

The other northern zones had proportions of household that consistently used fertilisers like the national proportions. Fig 20 shows the least consistent administrative zone in fertiliser usage, the South West. Only 1.8% (3) of households used fertilisers in all the three waves of data analysed. The low level of inputs usage and consistency is apparent in the other southern zones, with only 7% of households in the South-South and 13.7% in the South East that applied fertilisers in all three waves.

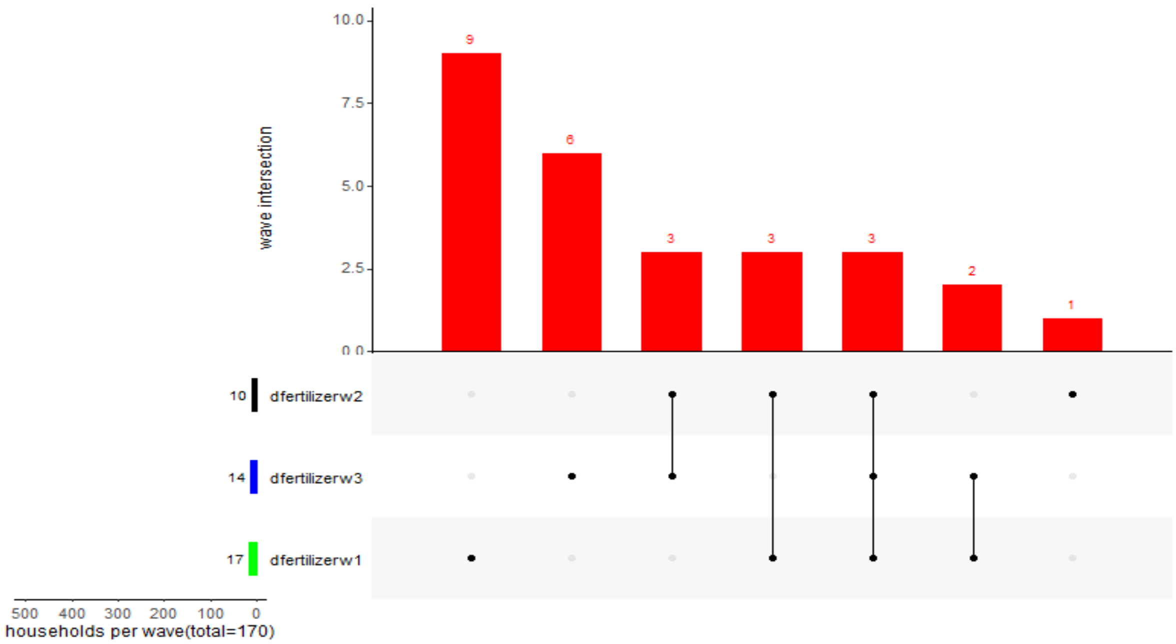

Figure 20. Consistency of fertilisers use in South West, Nigeria (wave 1-3)

4.2.2 Herbicides

Table 2 shows that more households in the North Central and North East used herbicides than in other zones. It is also interesting to note that household in the South West used more herbicides than the national proportions.

Zones	Wave 1(%)	Wave 2(%)	Wave 3(%)
Nigeria	25.8	29.9	35.1
North Central	45	61.2	61.4
North East	47.5	43.7	54.1
North West	20.5	26.3	29.6
South East	2.6	2.4	6
South-South	12.5	11.4	25.6
South West	29.4	37.7	39.4

Table 2. Household herbicide use in Nigeria (wave 1-3)

Fig 21 shows that only 12.8% (311) of households in the country used herbicides consistently in all three rounds. Herbicides are the second most consistently used input after fertilisers. It also shows that about 29.9% (725) of households used herbicides at least twice in the three data analysis rounds.

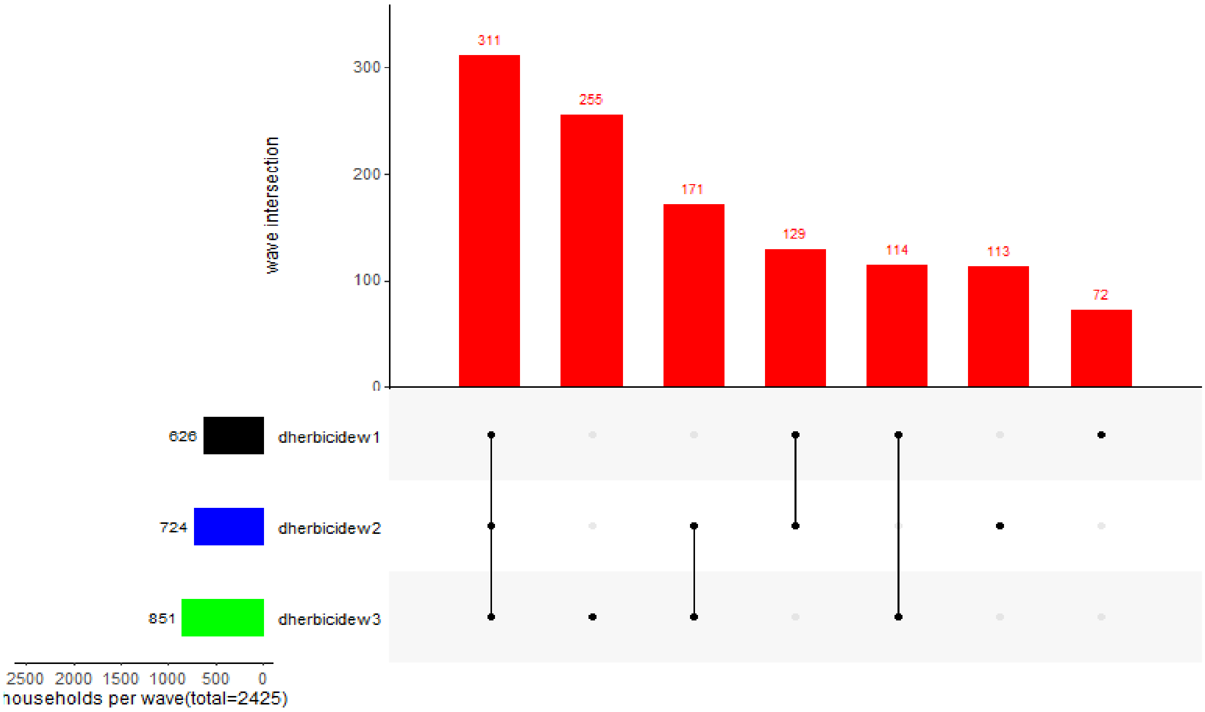

Figure 21. Consistency of herbicides usage in Nigeria (wave 1-3)

The zonal differences also continued with herbicides. The North Central showed the most consistency in the nation with 29.8% (129) of households. About 56.8% (246) of households used herbicides at least twice. The consistency proportions are similar for the North East, but the North West showed much less consistency in herbicide usage at 6% of households. This consistency level is lower than the South West with 12.4% of households.

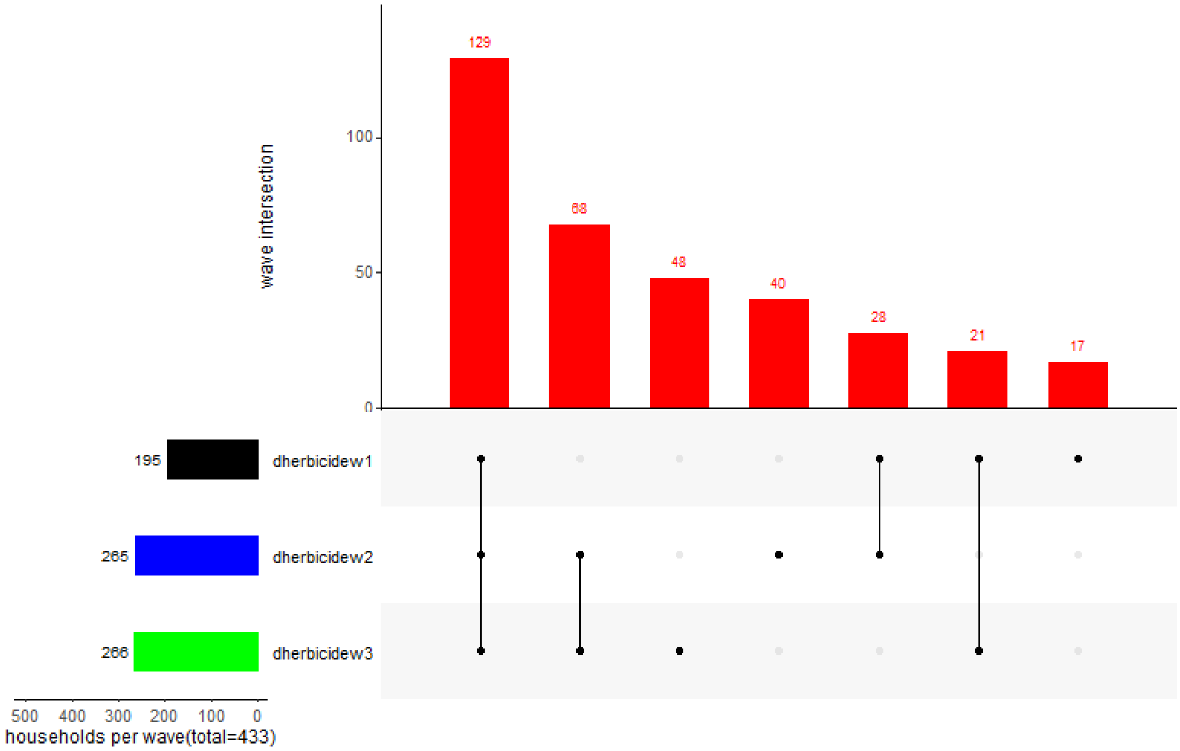

Figure 22. Consistency of herbicides usage in North Central, Nigeria (wave 1-3)

Fig 23 shows the least consistent zone with regards to herbicides usage, the South East. Only about 1% (5) of households used herbicides consistently.

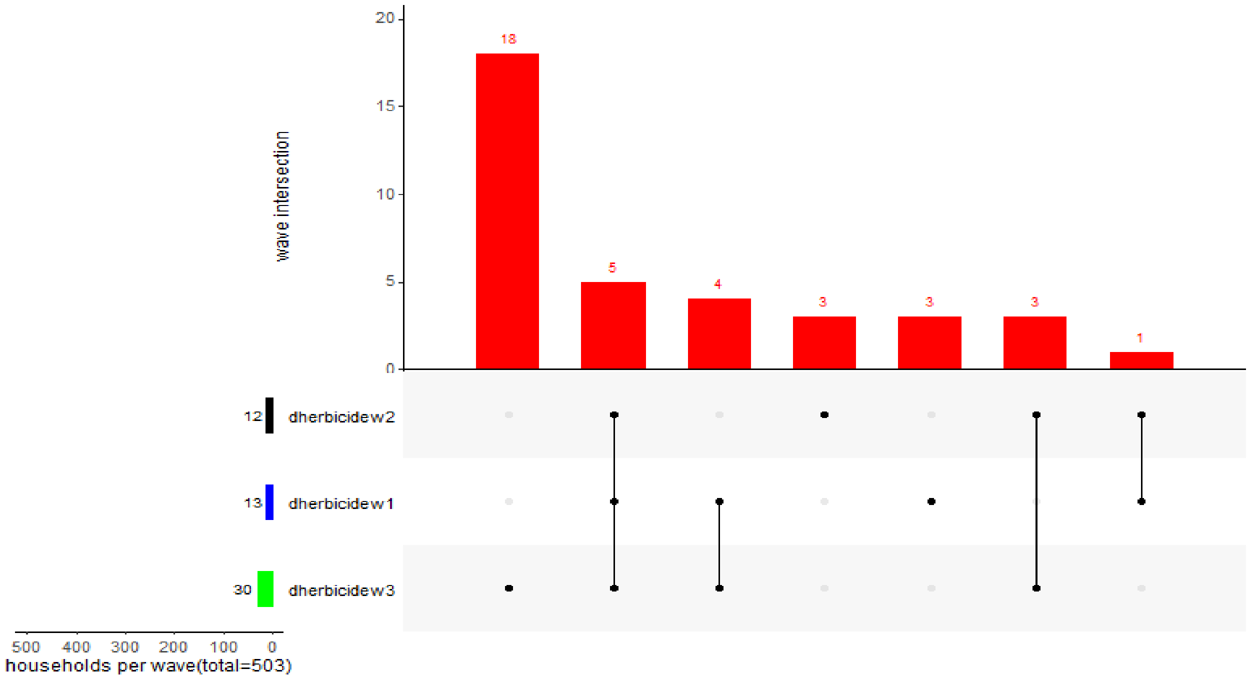

Figure 23. Consistency of herbicides use in South East, Nigeria (wave 1-3)

4.2.3 Pesticides

Table 3 shows the proportion of households that used pesticide in the three waves of data, nationally and across zones. A higher percentage of households used pesticides in the South West than in any other zones and more than the national proportions.

Zones	Wave 1 (%)	Wave 2 (%)	Wave 3 (%)
Nigeria	19.3	19.9	24.9
North Central	14.1	16.4	16.4
North East	21	17.9	26
North West	32	35.3	48
South East	7.2	4	4.8
South-South	4.8	3.3	5.5
South West	42.4	53.5	52.4

Table 3. Household pesticide use in Nigeria (wave 1-3)

Fig 24 shows that most households used pesticides just once in the three rounds of data analysed, with 23.5% (569) of households fitting this description. Only 6.4% (154) used pesticides consistently, and 17.2% (416) used pesticides at least twice.

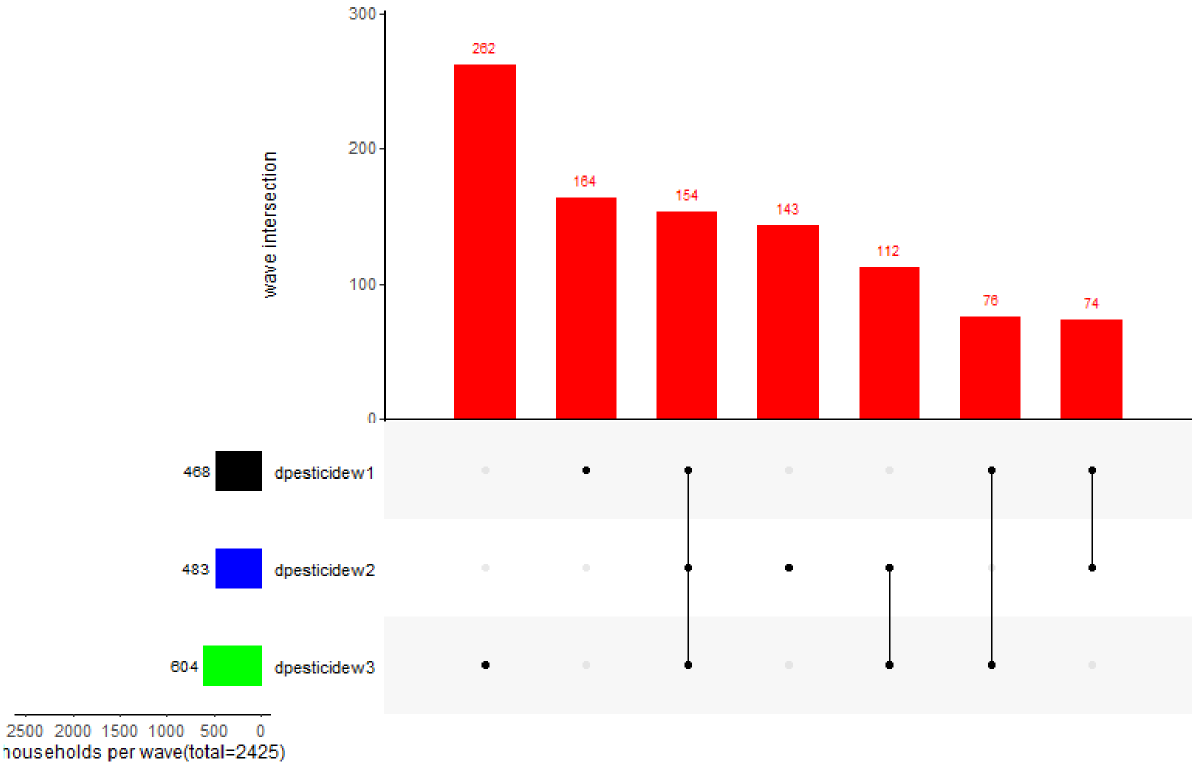

Figure 24. Consistency of pesticides usage in Nigeria (wave 1-3)

Fig 25 below shows that households in the South West used pesticides considerably more consistently than the national proportions, with 27.7% (47) of households. Also, more than half, 54.1% (92) of households used pesticides at least twice. Another administrative zone where households used pesticides considerably more than the national ratios is the North West, where 12.4% of households applied pesticides in all three rounds analysed.

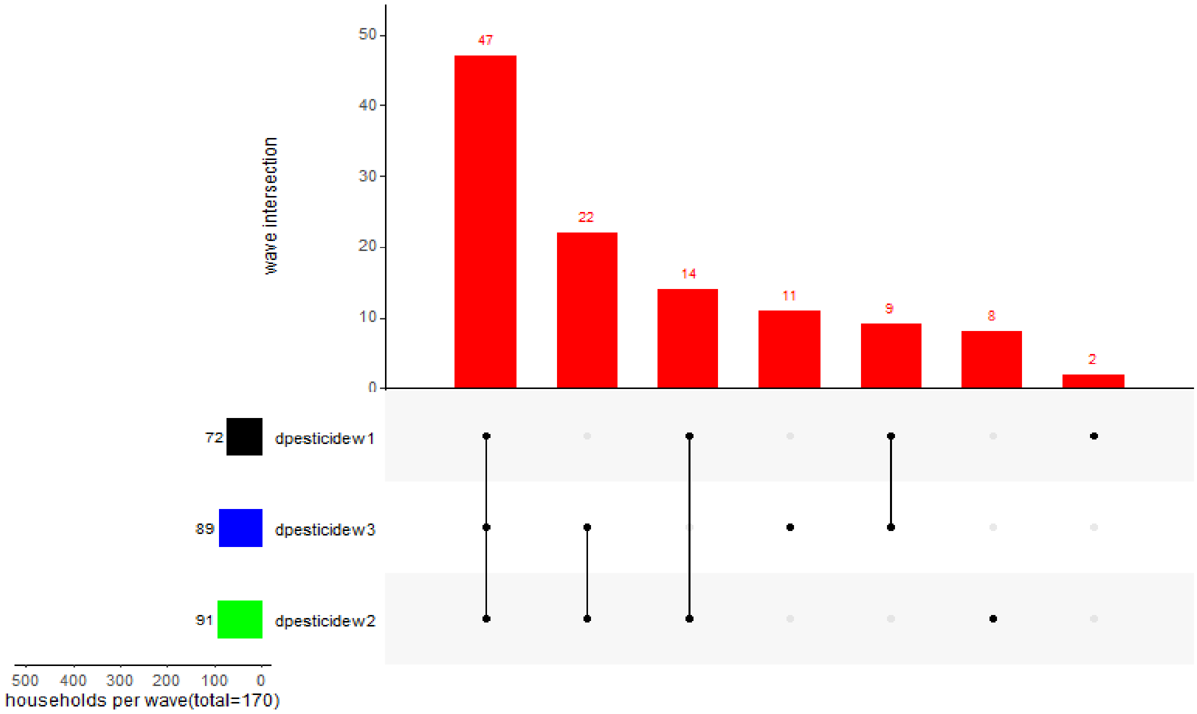

Figure 25. Consistency of pesticides usage in South West, Nigeria (wave 1-3)

4.2.4 Purchased Seeds

Table 4 shows the proportion of households that used purchased seeds from wave one - wave three. A higher proportion of households in the South East used more purchased seeds than other regions.

Zones	Wave 1 (%)	Wave 2 (%)	Wave 3 (%)
Nigeria	36.2	27.3	33
North Central	21.7	12.2	18
North East	26.2	12	17.4
North West	37.6	34.9	41.2
South East	57.9	49.9	53.3
South-South	34.1	20.9	31.5
South West	32.9	21.8	24.1

Table 4 Households using purchased seeds in Nigeria (wave 1-3)

Only 7.3% (178) of households used purchased seeds in all three waves nationally, as seen in fig. 24 below. About 33.7% (816) of households used purchased seeds only once in the three waves, and 27.7% (672) used them at least twice in the three waves.

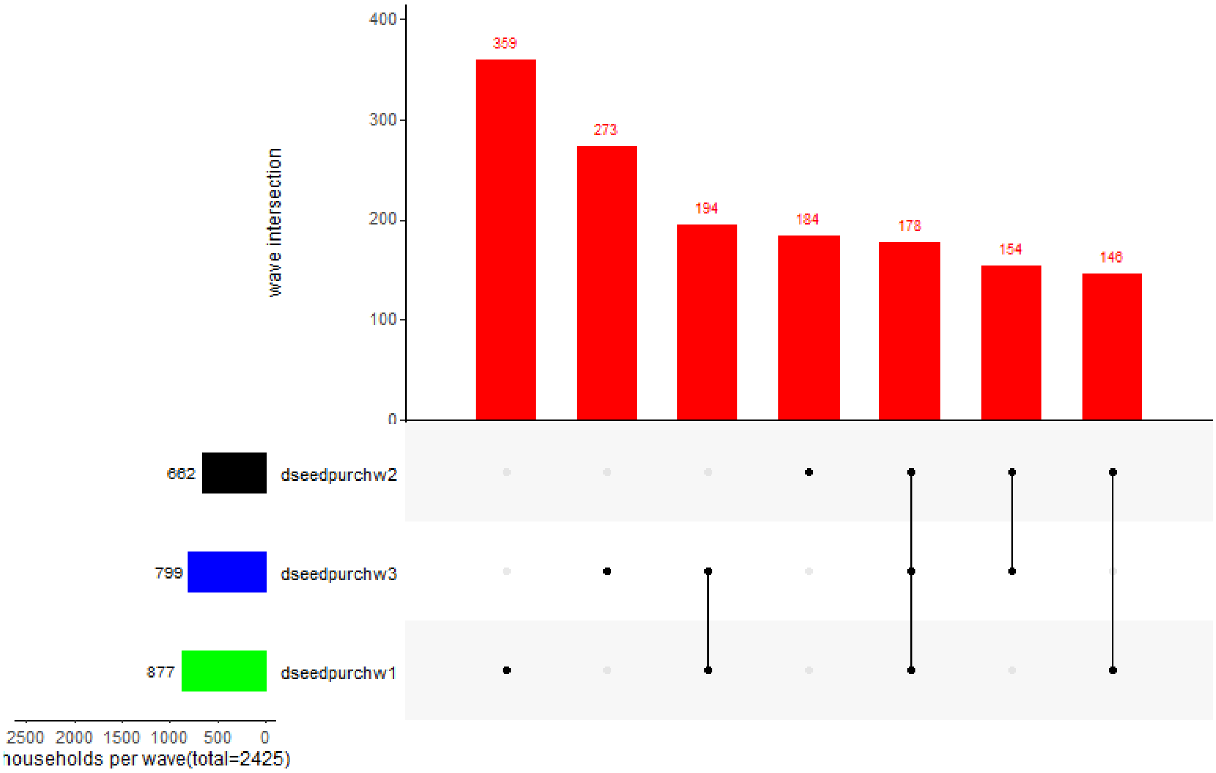

Figure 26. Consistency of using purchased seeds in Nigeria (wave 1-3)

It is also interesting to look at the proportions of households that used purchased seeds consistently in the South-East because a higher proportion of households in the region used purchased seeds compared to other zones and the national proportions. As seen in fig. 27 below, 20.3% (102) of households used purchased seeds in all three waves. Most households used purchased seeds at least twice in the three waves, with 53.1% (267) of households fitting this description. Also, 34.6% (174) of households used purchased seeds only once in the three waves.

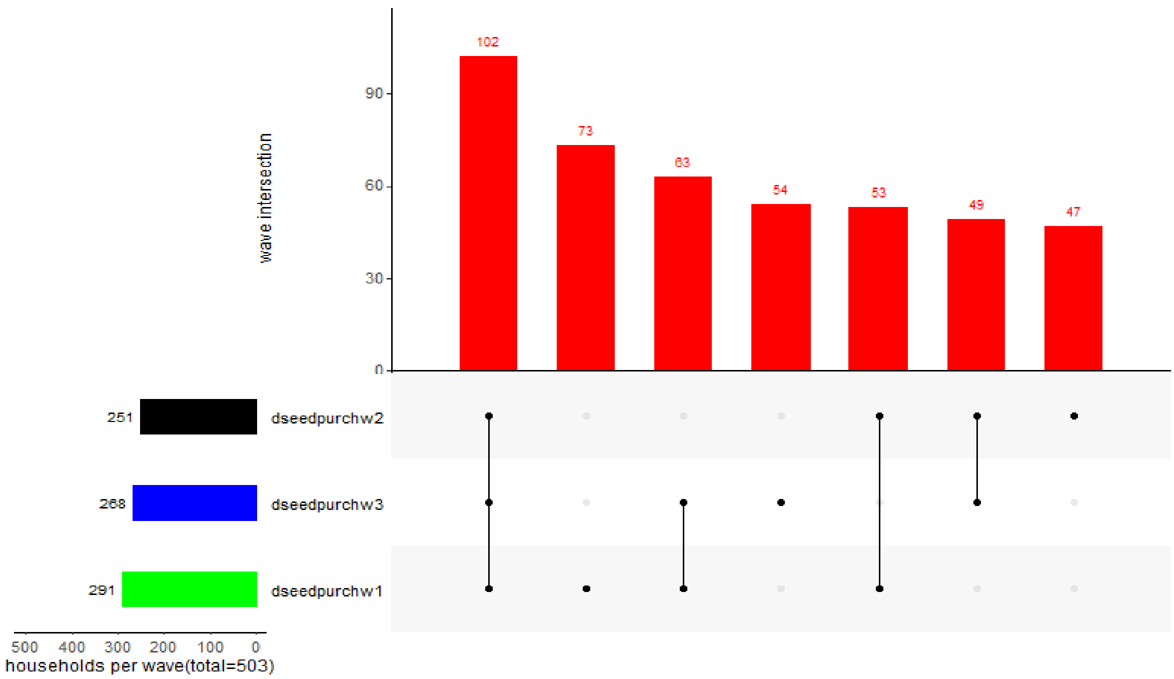

Figure 27. Consistency of purchased seeds use in South East, Nigeria (wave 1-3)

4.2.5 Irrigation

Irrigation is the least used inputs amongst the five inputs plotted in this section. Table 5 below shows the proportion of households that irrigated their plots within the period of data collected in wave 1 to wave 3. Very few households irrigated their plots consistently within the waves analysed, about 0.5% nationally. There are no considerable differences between the analysis on a farm plot level.

Zones	Wave 1 (%)	Wave 2 (%)	Wave 3 (%)
Nigeria	4.2	2.1	1.9
North Central	4.9	4.2	1.4
North East	3.9	1.1	1.1
North West	7.3	4.5	4.5
South East	2.2	0	0.6
South South	1.5	0	0.7
South West	2.9	0.6	1.8

Table 5. Households that irrigated their plots in Nigeria (wave 1-3)

4.3 Research Question Three – Credit and Input Use

In this section, the results of the third research question stated below is presented.

Research question 3: To what extent do Nigerian farmers have access to credit, and how does credit accessibility affect inputs use (single-use and complementary use)?

4.3.1 Summary Statistics of Regression Variables

Table 6 below shows the mean, standard deviation, minimum and maximum for all the variables present in the panel regression analysis. There are 1396 households for every wave of data collection, and three waves of data were used in the regression leading to a total of 4188 observations. It is a balanced panel dataset as only households present in all data collection waves were included in the analysis. Variables with a minimum of 0 and a maximum of 1 are all binary variables, and the means are interpreted as the percentage of households that fall into the group represented by 1. The logarithm of income variables was used rather than the absolute values to correct the income variables' skewness.

As shown in table 6, 50.7% of the panel households used fertilisers, 33.5% used herbicides, 22.3% used pesticides, 33.9% used purchased seeds, and the average complementary use of input was the use of one input. The variables described above are the dependent variables in the analysis. The remaining variables in the table are all independent or explanatory. As seen in the table, 11% of the households were in the urban area. The average age of the household head was 34 years. A male household head was present in 91% of the households. The mean household head years of education was five years. The mean distance to market was 73 kilometres, mean annual temperature was 26.4°c, mean annual precipitation was 1436mm, mean plot size was 10,043m2. About 11% of the households received related extension services, 25.5% of households used machinery and only about 2% worked on other people´s farms as off-farm labour. About 55.8% of the households cultivated some cash crops. Credit has been split into formal and informal credit. Only 5.7% of households received formal credit, while 19.8% of households received informal credit.

Variables	mean	sd	min	max
dfertiliser (1 = yes)	0.51	0.50	0.00	1.00
dherbicide (1 = yes)	0.34	0.47	0.00	1.00
dpesticide (1 = yes)	0.22	0.42	0.00	1.00
dseedpurch (1 = yes)	0.34	0.47	0.00	1.00
complementary	1.40	1.05	0.00	4.00
sector (1 =urban)	0.11	0.31	0.00	1.00
hhheadage	51.65	14.14	17	112
hhheadgender (1 = male)	0.91	0.29	0.00	1.00
hhheadedu (years of education)	5.09	5.15	0.00	18.00
disttomarket (kms)	73.36	38.51	1.68	214.36
annualtemp ×10°c	263.65	10.37	220.00	288.00
meanannprec (mm)	1436.24	578.78	415.00	3325.00
Plotsize (sqm)	10043.09	15753.39	0.00	265033.00
dextension (1 = yes)	0.11	0.31	0.00	1.00
dmachinery (1 = yes)	0.25	0.44	0.00	1.00
offfarmlabour (1 = yes)	0.02	0.14	0.00	1.00
dcashcrop (1 = yes)	0.56	0.50	0.00	1.00
dformalcredit (1 = yes)	0.06	0.23	0.00	1.00
dinformalcredit (1 = yes)	0.20	0.40	0.00	1.00
cropincomelog	3.29	2.17	0.00	7.01
otherincomelog	0.44	1.36	0.00	6.44
nonfarmincomelog	2.71	2.24	0.00	7.12
North Central	0.17	0.38	0.00	1.00
North East	0.17	0.38	0.00	1.00
North West	0.22	0.41	0.00	1.00
South East	0.24	0.42	0.00	1.00
South South	0.13	0.34	0.00	1.00
South West	0.07	0.26	0.00	1.00
N	4188	1396	T=3	

Table 6 National summary statistics for variables used in the regression

4.3.2 Fertiliser Analysis

This subsection contains the panel logit regression results on the relationship between credit and the use of fertiliser. Table 7 below presents the panel logit regression results with fertiliser use as the dependent variable. We see that keeping all other variables constant, the distance to market negatively relates to fertiliser use. The same goes for the annual temperature, and they are both statistically significant at the 0.1% interval. To interpret the results more specifically, if the distance to market increases by 1km, the probability that the household will use fertiliser reduces by 0.0158, keeping all other variables constant at their mean. If the annual temperature increases by 1°c, the probability that a household will use fertiliser reduce by 0.0351, keeping all other variables constant. The use of machinery is statistically significant at a 1% interval; this means that keeping all other variables constant if a household uses machinery, the probability that the household will use fertiliser increases by 0.387 compared to households that did not use any machinery. Planting some cash crop and receiving extension is positively related to the probability of using fertilisers, and they are statistically significant at the 0.1% interval. Receiving formal credit or informal credit is statistically nonsignificant for the use of fertiliser. Although the interaction term of receiving extension and receiving formal credit has a negative relationship with the probability of using fertiliser, it is statistically significant at the 5% interval. Unsurprisingly income from crops planted has a positive relationship with the probability of using fertiliser, and it is statistically significant at the 0.1% interval. Income from household´s non-farm enterprises also has a positive relationship with the probability of using fertiliser, and it is statistically significant at the 1% interval.

t statistics in parentheses		
	Logit	
dfertiliser	Coeff.	z
wave_2	-0.231*	(-2.24)
wave_3	-0.214	(-1.88)
sector	0.343	(1.63)
hhheadage	-0.00871	(-1.77)
hhheadgender	0.293	(1.41)
hhheadedu	0.0252	(1.95)
disttomarket	-0.0158***	(-8.11)
annualtemp	-0.0351***	(-5.24)
meanannprec	-0.000135	(-0.52)
plotsize	0.00000491	(1.39)
dmachinery	0.387**	(3.17)
offfarmlabour	0.206	(0.57)
dcashcrop	0.534***	(4.58)
dextension	0.649***	(3.34)
dformalcredit	0.239	(1.01)
dinformalcredit	0.0898	(0.70)
dextension#dformalcredit	-1.319*	(-2.04)
dextension#dinformalcredit	-0.207	(-0.55)
cropincomelog	0.112***	(4.25)
otherincomelog	0.0689	(1.71)
nonfarmincomelog	0.0728**	(2.81)
North East	0.212	(0.92)
North West	1.840***	(7.23)
South East	-0.439	(-1.56)
South South	-1.958***	(-5.08)
South West	-3.784***	(-9.87)
_cons	9.887***	(5.16)
lnsig2u	0.933***	(7.88)
N	4188	

Table 7. Logit panel regression results for fertilisers

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

To get a more in-depth look into the effect of credit, the following tables will show the interesting zonal differences with respect to the credit variables (dformalcredit, dinformalcredit, dextension#dformalcredit, and dextension#dinformalcredit). The credit variables were mostly statistically nonsignificant in the zones, except in the South-South. As shown in Table 8 below, many of the statistically significant variables at the national level are statistically insignificant, and the significance level of the significant variables is considerably lower. Receival of formal credit is statistically significant at a 5% interval in the South-South, and the relationship is positive. i.e., keeping all other variables constant, if a household in the South-South receives formal credit, the probability of using fertiliser increases by 1.160 compared to households that did not receive formal credit. It is also worthy to note that the whole South-South model is not highly significant, as it is only statistically significant at the 5% interval.

t statistics in parentheses		
	Logit	
dfertiliser	Coeff.	z
wave_2	-0.264	(-0.59)
wave_3	-1.402**	(-2.94)
sector	1.676	(1.82)
hhheadage	-0.0158	(-0.78)
hhheadgender	0.343	(0.43)
hhheadedu	-0.0248	(-0.42)
disttomarket	-0.0203*	(-2.15)
annualtemp	0.0165	(0.22)
meanannprec	-0.00134	(-1.51)
plotsize	-0.0000114	(-0.62)
dmachinery	-0.899	(-1.35)
offfarmlabour	-0.271	(-0.22)
dcashcrop	0.505	(0.97)
dextension	2.075*	(2.12)
dformalcredit	1.160*	(2.28)
dinformalcredit	0.631	(1.16)
dextension#dinformalcredit	-0.304	(-0.10)
cropincomelog	0.0630	(0.64)
otherincomelog	0.0216	(0.19)
nonfarmincomelog	0.124	(1.16)
_cons	-2.804	(-0.15)
lnsig2u	2.297***	(5.89)
N	548	

Table 8. Logit panel regression for fertilisers in the South-South

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

The tables for the other zonal regressions are not presented here as they are not different from the national regression when considering the credit variables.

4.3.3 Herbicide Analysis

Table 9 shows that the probability of using herbicides also increases when the household head is a male compared to being a female, keeping all other variables constant. The plot size relationship is also statistically significant in the positive direction, although with a much lower coefficient. Households that receive formal credit and informal credit also have a higher probability of using herbicides than households that did not receive any of the credits. The credit variables are statistically significant at the 1% and 5% interval, respectively. The interaction terms are nonsignificant, and crop sales' income is positively related to herbicide use with statistical significance at the 0.1% interval.

t statistics in parentheses		
	Logit	
dherbicide	Coeff.	Z
wave_2	0.217*	(2.03)
wave_3	0.873***	(6.90)
sector	0.176	(0.81)
hhheadage	0.000812	(0.16)
hhheadgender	0.727*	(2.40)
hhheadedu	0.0217	(1.56)
disttomarket	0.00344	(1.88)
annualtemp	0.0207***	(3.55)
meanannprec	0.000544*	(1.97)
plotsize	0.0000134***	(3.87)
dmachinery	0.263*	(2.07)
offfarmlabour	0.638	(1.77)
dcashcrop	0.493***	(3.72)
dextension	0.407*	(2.22)
dformalcredit	0.710**	(3.27)
dinformalcredit	0.337*	(2.34)
dextension#dformalcredit	-0.0102	(-0.02)
dextension#dinformalcredit	-0.246	(-0.67)
cropincomelog	0.111***	(4.21)
otherincomelog	-0.0321	(-0.81)
nonfarmincomelog	0.0377	(1.38)
North East	-0.444	(-1.90)
North West	-1.457***	(-5.64)
South East	-5.222***	(-12.86)
South South	-3.089***	(-8.69)
South West	-1.643***	(-5.83)
_cons	-8.106***	(-4.88)
lnsig2u	0.944***	(7.21)
N	4188	

Table 9. Logit panel regression results for herbicides

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

As seen in the fertiliser analysis, the administrative zones differ significantly compared to the North Central. Therefore, a more in-depth look will be taken into the zones with respect to the credit variables. The most interesting results are presented below.

As shown in table 10, receiving formal credit and informal credit is not statistically significant for North Central households. However, the interaction terms between receiving extension and formal and informal credit are statistically significant at the 5% interval with a negative relationship with the use of herbicides. We see that keeping all other variables constant, the probability of using herbicides reduces by 3.131 if a household receives extension service and formal credit compared to households that did not receive both. The impact is slightly lower for households that receive extension service and informal credit with a 2.264 reduction in probability compared to households that did not receive both. The percentage increase in other income such as grants, interests, and transfers also has a positive relationship with the use of herbicides in the North Central, with a 0.237 increase in the probability of using herbicides for a 1% increase in other income, statistically significant at the 1% interval. The distance to market is negatively related and highly statistically significant for using herbicides in the North Central.

t statistics in parentheses		
	Logit	
dherbicide	Coeff.	z
wave_2	0.789***	(3.32)
wave_3	1.247***	(4.30)
sector	1.760***	(3.75)
hhheadgender	-0.127	(-0.35)
disttomarket	-0.0217***	(-5.33)
annualtemp	0.0593***	(7.01)
meanannprec	-0.00226**	(-2.62)
hhheadage	-0.0258**	(-2.90)
hhheadedu	0.0293	(1.21)
plotsize	0.0000163	(1.81)
dmachinery	0.0618	(0.26)
offfarmlabour	0.648	(0.73)
dcashcrop	0.287	(1.42)
dextension	2.148**	(2.62)
dformalcredit	0.634	(1.21)
dinformalcredit	0.169	(0.72)
dextension#dformalcredit	-3.131*	(-2.37)
dextension#dinformalcredit	-2.264*	(-2.18)
cropincomelog	0.0227	(0.45)
nonfarmincomelog	-0.0904	(-1.69)
otherincomelog	0.237**	(3.10)
_cons	-9.812***	(-4.29)
lnsig2u	-0.113	(-0.24)
N	729	

Table 10. Logit panel regression for herbicides in the North Central

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

Table 11 shows that only informal credit among the credit-related variables is statistically significant for herbicides in the North West, with a positive relationship. Also, income from non-farm enterprises is positively related and statistically significant at the 5% interval. Crop income is positively related and significant as with the national analysis. Distance to market is statistically significant at the 5% interval, although positively related.

t statistics in parentheses		
	Logit	
dherbicide	Coeff.	z
wave_2	0.610**	(2.90)
wave_3	0.775**	(3.12)
sector	0.233	(0.60)
hhheadage	-0.00574	(-0.66)
hhheadgender	1.301	(1.09)
hhheadedu	-0.00801	(-0.34)
disttomarket	0.00633*	(1.96)
annualtemp	0.0441***	(3.32)
meanannprec	0.00514***	(7.07)
plotsize	0.0000157*	(2.50)
dmachinery	1.079***	(3.69)
offfarmlabour	0.589	(0.98)
dcashcrop	0.235	(0.98)
dextension	0.0789	(0.34)
dformalcredit	0.559	(0.80)
dinformalcredit	1.053**	(2.62)
dextension#dformalcredit	1.187	(0.98)
dextension#dinformalcredit	-0.942	(-1.68)
cropincomelog	0.216***	(4.83)
otherincomelog	-0.287	(-1.72)
nonfarmincomelog	0.108*	(2.01)
_cons	-20.60***	(-4.84)
lnsig2u	0.0250	(0.07)
N	912	

Table 11. Logit panel regression for herbicides in the North West

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

As seen in Table 12, the number of households that received formal credit in the South East was too small for the estimation method to yield any coefficient. Informal credit is also nonsignificant here, differing from the national results.

t statistics in parentheses		
	Logit	
dherbicide	Coeff.	z
wave_2	0.0427	(0.05)
wave_3	1.656	(1.94)
sector	0	(.)
hhheadgender	2.242*	(2.28)
disttomarket	-0.0154	(-0.89)
annualtemp	0.189**	(2.81)
meanannprec	-0.0120***	(-5.51)
hhheadage	0.0435	(1.49)
hhheadedu	-0.0272	(-0.32)
plotsize	0.00000376	(0.05)
dmachinery	0.350	(0.49)
offfarmlabour	0	(.)
dcashcrop	2.130***	(3.43)
dextension	0.978	(0.82)
dformalcredit	0	(.)
dinformalcredit	0.304	(0.45)
dextension#dformalcredit	0	(.)
dextension#dinformalcredit	0.680	(0.31)
cropincomelog	0.0406	(0.19)
nonfarmincomelog	-0.102	(-0.56)
otherincomelog	0.380	(1.39)
_cons	-39.09*	(-2.26)
lnsig2u	1.361*	(2.57)
N	808	

Table 12. Logit panel regression for herbicides in the South East

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

The South East results are like the other southern zones (South-South and South-West) in that formal and informal credit are statistically nonsignificant.

4.3.4 Pesticide Analysis

Table 13 shows that mean annual precipitation has a negative relationship with pesticide use, statistically significant at the 1% interval. Planting some cash crop has a positive relationship, and it is highly significant. Other variables that have a statistically significant relationship with the use of pesticides are extension, formal credit, crop income, and other income. As mentioned, one of the variables of interest has a statistically significant relationship with pesticides. Households that received formal credit has 0.868 more probability of using pesticides, keeping all other variables constant, and this is statistically significant at the 0.1% interval. The table also shows that the North West and the South West differ from the North Central, and they are both significant at the 0.1% interval.

t statistics in parentheses		
dpesticide	Coeff.	z
wave_2	-0.153	(-1.31)
wave_3	0.494***	(4.09)
sector	0.0410	(0.21)
hhheadage	-0.00214	(-0.43)
hhheadgender	0.535	(1.89)
hhheadedu	0.0197	(1.57)
disttomarket	-0.00243	(-1.41)
annualtemp	-0.00433	(-0.79)
meanannprec	-0.000824**	(-2.88)
plotsize	0.00000318	(0.96)
dmachinery	0.139	(1.21)
offfarmlabour	-0.284	(-0.73)
dcashcrop	1.155***	(8.37)
dextension	0.394*	(2.27)
dformalcredit	0.868***	(3.51)
dinformalcredit	0.118	(0.80)
dextension#dformalcredit	-0.0162	(-0.02)
dextension#dinformalcredit	0.392	(1.12)
cropincomelog	0.114***	(3.99)
otherincomelog	0.0850*	(2.21)
nonfarmincomelog	0.0387	(1.46)
North East	-0.421	(-1.90)
North West	0.808***	(3.55)
South East	-0.491	(-1.57)
South-South	-0.680	(-1.80)
South West	1.623***	(6.10)
_cons	-1.508	(-0.94)
lnsig2u	0.469**	(2.98)
N	4188	

Table 13. Panel logit regression results for pesticides

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

For a more comprehensive analysis, the zonal differences are analysed to see if there is a difference with regards to the credit variables. Table 14 shows that formal credit and informal credit have no statistically significant relationship with the use of pesticides. However, households that receive extension service and informal credit have a statistically significant higher probability of using pesticides than the households that did not receive extension service and informal credit if all variables remain constant at their mean. The number of household head that is not male is very low; therefore, the estimation method could not yield a coefficient, the same for households that received extension and formal credit.

t statistics in parentheses		
	Logit	
dpesticide	Coeff.	z
wave_2	-0.0881	(-0.32)
wave_3	0.448	(1.48)
sector	-0.858	(-1.12)
hhheadage	-0.00437	(-0.38)
hhheadgender	0	(.)
hhheadedu	0.0184	(0.69)
disttomarket	-0.0141***	(-3.58)
annualtemp	-0.0170	(-0.89)
meanannprec	0.000570	(0.96)
plotsize	0.00000730	(1.39)
dmachinery	-0.310	(-0.99)
offfarmlabour	-0.254	(-0.20)
dcashcrop	1.265*	(2.27)
dextension	0.964	(1.69)
dformalcredit	0.971	(1.43)
dinformalcredit	-0.00843	(-0.02)
dextension#dformalcredit	0	(.)
dextension#dinformalcredit	3.271*	(2.32)
cropincomelog	0.167*	(2.54)
otherincomelog	0.185*	(2.45)
nonfarmincomelog	-0.0167	(-0.27)
_cons	1.380	(0.28)
lnsig2u	0.525	(1.44)
N	702	

Table 14. Logit panel regression for pesticides in the North East

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

The North Central and the South East do not differ from the national analysis with regards to the credit variables. The North West and South West differ because none of the credit variables was statistically significant. Table 15 below shows that receiving informal credit is positively related and statistically significant for using pesticides in the South-South if all other variables remain constant. It is significant at the 5% interval, differing from the national results where formal credit is the significant credit variable.

t statistics in parentheses		
	Logit	
dpesticide	Coeff.	z
wave_2	-0.484	(-0.72)
wave_3	0.759	(1.35)
sector	0.437	(0.60)
hhheadage	-0.0120	(-0.61)
hhheadgender	1.859	(1.28)
hhheadedu	-0.0924	(-1.63)
disttomarket	-0.0198	(-1.37)
annualtemp	-0.0531	(-1.04)
meanannprec	-0.000848	(-0.92)
plotsize	0.0000144	(0.88)
dmachinery	-2.285*	(-2.56)
offfarmlabour	0	(.)
dcashcrop	3.081***	(3.97)
dextension	1.199	(1.12)
dformalcredit	0.413	(0.56)
dinformalcredit	1.070*	(2.09)
dextension#dformalcredit	0	(.)
dextension#dinformalcredit	0	(.)
cropincomelog	-0.0507	(-0.31)
otherincomelog	-0.224	(-1.54)
nonfarmincomelog	-0.0285	(-0.26)
_cons	11.91	(0.88)
lnsig2u	1.034	(1.91)
N	538	

Table 15. Logit panel regression for pesticides in the South-South

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

4.3.5 Purchased Seeds Analysis

Table 16 below shows that the sector, annual temperature, mean annual precipitation, off-farm labour, extension, formal credit, income from crop sales, and other income are statistically significant. For credit, which is our primary explanatory variable of interest, we see that Households that receive formal credit have 0.465 more probability of using purchased seeds than households that did not receive formal credit if all other variables remain constant. This result is significant at the 5% interval. Informal credit and the credits interaction terms with extension are nonsignificant. Additionally, income from crop sales and other incomes such as grants, interest earnings, and transfers are positively related to the use of purchased seeds, and these variables are statistically significant at the 0.1% interval. The North West, South East, South-South are also different from the North Central.

t statistics in parentheses		
	Logit	
dseedpurch	Coeff.	z
wave_2	-0.544***	(-5.76)
wave_3	-0.161	(-1.74)
sector	0.516***	(3.56)
hhheadage	-0.00675	(-1.93)
hhheadgender	0.135	(0.87)
hhheadedu	0.00854	(0.91)
disttomarket	-0.000199	(-0.15)
annualtemp	-0.00997*	(-2.25)
meanannprec	-0.000558**	(-3.12)
plotsize	-0.00000349	(-1.17)
dmachinery	0.104	(1.03)
offfarmlabour	0.692**	(2.58)
dcashcrop	0.152	(1.59)
dextension	0.442**	(2.92)
dformalcredit	0.465*	(2.56)
dinformalcredit	0.216	(1.93)
dextension#dformalcredit	-0.707	(-1.31)
dextension#dinformalcredit	0.237	(0.80)
cropincomelog	0.0750***	(3.82)
otherincomelog	0.117***	(3.74)
nonfarmincomelog	0.0309	(1.60)
North East	-0.0842	(-0.45)
North West	0.916***	(5.28)
South East	2.469***	(11.67)
South-South	1.253***	(5.21)
South West	0.222	(0.95)
_cons	1.410	(1.12)
/		
lnsig2u	-0.446*	(-2.23)
N	4188	

Table 16. Panel logit regression results for purchased seeds

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

As usual, we analyze the zonal regressions to report the most interesting results with respect to the credit variables. As seen in table 17, households that receive formal credit are more likely to use purchased seeds than households that did not receive formal credit. The same goes for informal credit with a higher level of statistical significance, differing from the national analysis. Only the relationship between receiving formal credit and using purchased seeds is statistically significant out of the credit variables. Also, income from crop sales and other income is not statistically significant in the North Central. However, households with income from non-farm enterprises are more likely to use purchased seeds. If a household non-farm enterprise income increases by 1%, its probability of using purchased seeds increase by 0.126 if all other variables remain constant. This relationship is significant at the 5% interval.

t statistics in parentheses		
	Logit	
dseedpurch	Coeff.	z
wave_2	-0.914**	(-3.14)
wave_3	-0.0618	(-0.22)
sector	0.112	(0.22)
hhheadgender	-0.157	(-0.29)
disttomarket	0.00640	(1.61)
annualtemp	-0.0369***	(-4.85)
meanannprec	0.000433	(0.53)
hhheadage	-0.00415	(-0.41)
hhheadedu	0.0561*	(2.21)
plotsize	-0.0000210*	(-2.13)
dmachinery	0.217	(0.79)
offfarmlabour	1.343**	(2.60)
dcashcrop	0.326	(1.23)
dextension	0.269	(0.50)
dformalcredit	1.061*	(2.06)
dinformalcredit	1.138***	(4.10)
dextension#dformalcredit	0.568	(0.51)
dextension#dinformalcredit	0.258	(0.30)
cropincomelog	0.0630	(1.00)
nonfarmincomelog	0.126*	(2.24)
otherincomelog	0.139	(1.70)
_cons	5.989**	(2.92)
lnsig2u	-0.520	(-0.76)
N	729	

Table 17. Logit panel regression for use of purchased seeds in North Central

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

The credit variables relationship in the South East is like the North Central. In table 18, we see that the informal credit is positively related to the use of purchased seeds but with a lower level of significance at the 1% interval compared to the North Central. However, the coefficient of formal credit is not statistically significant in the North East. Income from non-farm enterprises is positively related to the use of purchased seeds and is not very different from the North Central relationship. The North-West zone yielded similar results, but informal credit was only significant at the 5% interval. The South-South and the South West are similar with regards to the credit variables as none of them is statistically significant.

t statistics in parentheses		
	Logit	
dseedpurch	Coeff.	z
wave_2	-1.356***	(-4.04)
wave_3	-0.616*	(-2.15)
sector	-1.333	(-1.58)
hhheadage	0.00652	(0.68)
hhheadgender	-1.726**	(-2.71)
hhheadedu	0.0241	(0.90)
disttomarket	0.00712*	(2.09)
annualtemp	-0.0179	(-1.00)
meanannprec	-0.000813	(-1.57)
plotsize	-0.00000108	(-0.23)
dmachinery	0.262	(0.82)
offfarmlabour	0.0167	(0.01)
dcashcrop	0.142	(0.38)
dextension	0.881	(1.50)
dformalcredit	-1.601	(-1.47)
dinformalcredit	0.785**	(2.72)
dextension#dformalcredit	0	(.)
dextension#dinformalcredit	-0.721	(-0.62)
cropincomelog	0.0227	(0.38)
otherincomelog	0.0929	(1.22)
nonfarmincomelog	0.139*	(2.21)
_cons	4.216	(0.88)
lnsig2u	-0.229	(-0.43)
N	712	

Table 18. Logit panel regression for use of purchased seeds in the North East

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

4.3.6 Complementary Use Analysis

As seen in Table 19, most of the independent variables are statistically significant, so the nonsignificant variables will be reported first. Household head age, mean annual precipitation, and outsourced labour to other farms (offfarmlabour) is nonsignificant in the model. We see that an urban household use more types of inputs compared to a rural household if all other variables are constant, with statistical significance at the 1% interval. The gender of the household head, household head years of education, plot size, and machinery use are all positively related to the use of more types of inputs by households. Also, households that have planted some cash crops use more types of inputs than households without cash crops. Additionally, a km increase in the distance to market leads to household use of more input reducing slightly by 0.00132, ceteris paribus.

The credit variables, extension and all income variables are statistically significant and positively related to using more types of inputs by households, although at varying levels of statistical significance. Households that received formal credit will use 0.206 more types of input compared to households that did not receive formal credit if all variables remain constant at their mean. The coefficient for informal credit is smaller at 0.082 and with lesser statistical significance at the 1% interval compared to receiving formal credit.

t statistics in parentheses		
	Poisson	
complementary	Coeff	z
sector	0.127***	(3.32)
hhheadage	-0.00127	(-1.26)
hhheadgender	0.139*	(2.54)
hhheadedu	0.00890***	(3.37)
disttomarket	-0.00132***	(-3.76)
annualtemp	-0.00229*	(-2.11)
meanannprec	-0.0000676	(-1.13)
plotsize	0.00000171**	(2.64)
dmachinery	0.0660*	(2.51)
offfarmlabour	0.119	(1.83)
dcashcrop	0.236***	(7.97)
dextension	0.181***	(6.35)
dformalcredit	0.206***	(4.27)
dinformalcredit	0.0821**	(3.00)
cropincomelog	0.0430***	(7.59)
otherincomelog	0.0224*	(2.57)
nonfarmincomelog	0.0153**	(2.78)
North East	-0.0440	(-0.92)
North West	0.191***	(4.25)
South East	-0.166*	(-2.44)
South South	-0.560***	(-5.83)
South West	-0.288***	(-4.73)
_cons	0.638*	(1.96)
lnalpha	-16.59***	(-33.10)
N	4188	

Table 19 Poisson panel regression for complementary input use in Nigeria

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Like with the individual use of inputs, the difference between the administrative zones and the North Central is significant except for the North East. In the following paragraphs, we dig deeper into why these zonal variables are statistically significant. Only the most interesting results with respect to the credit variables are reported below. Table 20 below shows that formal credit is not statistically significant for complementary use in the North Central, but informal credit is still positively related to complementary use. Incomes from crop sales and non-farm enterprises are also statistically nonsignificant, differing from the national results. The other northern zones are like the North Central in the household complementary inputs use relationship with the credit variables. However, income from crop sales is statistically significant in the North East and North West.

t statistics in parentheses		
	Poisson	
complementary	Coeff.	z
wave_2	-0.0322	(-0.66)
wave_3	0.127*	(2.29)
sector	0.201	(1.95)
hhheadage	-0.00629**	(-2.79)
hhheadgender	0.0725	(0.60)
hhheadedu	0.0157**	(2.95)
disttomarket	-0.00563***	(-6.15)
annualtemp	-0.000444	(-0.32)
meanannprec	-0.000832***	(-3.67)
plotsize	0.00000345*	(2.26)
dmachinery	-0.00140	(-0.03)
offfarmlabour	0.263**	(2.61)
dcashcrop	0.170**	(3.18)
dextension	0.0576	(0.93)
dformalcredit	0.0403	(0.53)
dinformalcredit	0.122*	(2.36)
cropincomelog	0.00931	(0.77)
otherincomelog	0.0647***	(4.37)
nonfarmincomelog	-0.00262	(-0.22)
_cons	1.970***	(3.92)
lnalpha	-18.60***	(-10.50)
N	729	

Table 20. Poisson panel regression for complementary input use in North Central

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

As shown in Table 21 below, formal credit is statistically significant in the South East. It is significant at the 1% interval. Most of the explanatory variables do not have a statistically significant relationship with complementary inputs use in the South East, and the ones that do are mostly at the 5% interval. Planting some cash crop has the highest level of statistical significance at 0.1% interval, and it has a positive relationship.

t statistics in parentheses		
	Poisson	
complementary	Coeff.	z
wave_2	-0.194***	(-3.37)
wave_3	-0.0887	(-1.48)
sector	0.111	(1.44)
hhheadgender	0.145*	(1.98)
disttomarket	-0.00372*	(-2.32)
annualtemp	0.00927	(1.56)
meanannprec	-0.0000651	(-0.30)
hhheadage	-0.00373	(-1.44)
hhheadedu	-0.00567	(-0.83)
plotsize	0.00000418	(1.11)
dmachinery	0.207**	(2.93)
offfarmlabour	-0.0565	(-0.39)
dcashcrop	0.286***	(5.02)
dextension	0.0885	(0.71)
dformalcredit	0.345**	(3.19)
dinformalcredit	-0.116	(-1.89)
cropincomelog	0.0401*	(2.46)
nonfarmincomelog	0.0204	(1.54)
otherincomelog	0.0456*	(2.16)
_cons	-2.199	(-1.24)
/		
lnalpha	-16.67***	(-26.94)
N	990	

Table 21. Poisson panel regression for complementary input use in South East

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

In Table 22 below, we see that formal credit and informal credit both have statistically significant relationships with complementary use for agricultural households in the South-South of Nigeria, like the national level, albeit with differences in the level of significance. They are also positively related to complementary input use. The mean annual precipitation has the highest level of significance. However, with a minor effect, interestingly, the sign is negative, i.e., with an additional mm of precipitation, the household use of more inputs reduces. Also, none of the income variables is significant.

t statistics in parentheses		
	Poisson	
complementary	Coeff.	z
wave_2	-0.250*	(-2.19)
wave_3	0.116	(1.20)
sector	0.319	(1.58)
hhheadgender	0.282	(1.51)
disttomarket	-0.00114	(-0.54)
annualtemp	0.0304**	(2.92)
meanannprec	-0.000785***	(-4.94)
hhheadage	-0.00415	(-1.00)
hhheadedu	-0.00442	(-0.40)
plotsize	0.00000489	(1.32)
dmachinery	-0.456*	(-2.40)
offfarmlabour	-0.0581	(-0.15)
dcashcrop	0.435**	(3.14)
dextension	0.615*	(1.98)
dformalcredit	0.331**	(2.66)
dinformalcredit	0.245*	(2.22)
cropincomelog	0.0196	(0.85)
nonfarmincomelog	0.0261	(1.23)
otherincomelog	0.0555*	(2.04)
_cons	-6.972*	(-2.49)
lnalpha	-2.588	(-0.99)
N	549	

Table 22. Poisson panel regression for complementary input use in South-South

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

In Table 23 below, we see that formal credit has a statistically significant relationship with complementary use for agricultural households in the South West of Nigeria. Also, Income from crop sales and income from non-farm enterprises are statistically significant at the 1% interval and positively related, i.e., if income from crop sales increases by 1%, households use 0.123 more types of inputs ceteris paribus. For income from non-farm enterprises, the effect is lesser at 0.0567 for a 1% increase in the income if all other variables remain constant at their mean.

t statistics in parentheses		
complementary		
sector	0.234*	(2.42)
hhheadgender	0.336	(1.35)
disttomarket	-0.00898***	(-4.11)
annualtemp	-0.0322*	(-2.50)
meanannprec	0.000624	(1.35)
hhheadage	-0.00348	(-0.77)
hhheadedu	-0.00505	(-0.45)
plotsize	0.00000112	(0.39)
dmachinery	-0.136	(-1.89)
offfarmlabour	-0.312	(-1.79)
dcashcrop	0.275	(1.83)
dextension	0.278**	(2.73)
dformalcredit	0.228*	(2.06)
dinformalcredit	0.0816	(0.79)
cropincomelog	0.123**	(2.75)
nonfarmincomelog	0.0567**	(2.79)
otherincomelog	0.00672	(0.32)
_cons	7.488*	(2.29)
lnalpha	-16.03***	(-11.21)
N	294	

Table 23. Poisson panel regression for complementary input use in the South West

Note: * p < 0.05, ** p < 0.01, *** p < 0.001

5. Discussion

Since the results have been interpreted above, the following considerations will be taken in discussing the three research questions: The implications of the results, limitations of the analysis, and recommendations will be made where possible.

5.1 Complementary Use of Inputs

For research question one, the plot level analysis is best suited to the operational definition of complementary use. It is important to note that this study focuses on the analysed inputs' synergistic use on the same plots. Unsurprisingly fertilisers are the most used input in the national sample studied across the three waves. This result corroborates with the results from Akramov (2009); Saweda et al. (2014); and Sheahan & Barrett (2014) in being the most used inputs. Looking at the usage pattern, we see that inputs are primarily used individually, fitting into the narratives of the majority of the papers reviewed. The most common complementary usage patterns are using fertilisers and herbicides, using fertilisers and purchased seeds, and then using fertilisers and pesticides. These patterns are similar to the complementary patterns reported by Sheahan & Barrett (2014). Inorganic fertilisers are the most paired input with other inputs, and fertiliser – herbicide complementary use is the most common pairing. This makes sense since when inorganic fertilisers are applied on plots, the increase in soil fertility will also aid the growth of weeds, and this improved environment for weed growth warrants the need for herbicides (Sheahan & Barrett, 2014).

The fertiliser usage patterns are similar in the northern zones, where more plots are applied with inputs compared to the southern zones. The highest level of fertiliser use is seen in the North West, where on average, over 70% of the plots are applied with fertilisers. The high level of fertiliser application in the north could be due to the lower soil fertility in the area. On the other hand, the southern zones apply agrochemicals on more plots than inorganic fertilisers, probably because of the higher soil fertility in the southern part of Nigeria. Although the inputs are mainly applied individually in the southern zones, the complementary application of pesticides and herbicides was the most common usage pattern, while the use of purchased seeds was the most common individual use pattern. This individual use of purchased seeds in the southern zones is understandable since using improved seeds could mean disease and pest resistance and resilience in competition with weed. The agroecological characteristics of the southern zones intuitively support the input usage patterns, and this could also be due to the types of crops planted. The zonal variations are pronounced, especially between the Northern zones and the Southern zones in Nigeria, similar to Sheahan & Barrett (2014) 's findings for the different countries in Sub-Saharan Africa.

The national average for applying herbicides on plots that have had fertilisers applied on them was about 20%, while for fertilisers and purchased seeds for plots that had fertilisers applied on them was an average of 15%. Even though the proportion of plots with fertiliser applied on them was relatively stable throughout the three waves, the use of purchase seeds fluctuated a bit. This is in line with World Bank (2014) findings that farmers reuse purchased seeds for several seasons before purchasing another batch. Therefore, the benefits of using improved seeds are probably not consistently sustained. Another interesting pattern supported by Uduji & Okolo-Obasi (2018) is the fluctuation in the position of using only purchased seeds at the household level nationally. In the first wave, purchased seeds were the most common individual use of inputs; this dropped behind fertiliser to second place in wave 2, and then back to most common individual input application in wave 3.

Interestingly, on average, it seems like using any of the inputs together on the same plot is more common than we would think. At the highest in wave 3 (2015-2016), 33.5% of the sampled plots (5721) used any of the inputs synergistically. This result implies that a considerable number of farmers are managing to exploit the synergistic benefits. Also, the highest mixed-use period is the last wave, indicating that this usage pattern is becoming more popular. Although the 2nd wave of the data showed a lesser proportion of mixed usage than the 1st wave, the fluctuation in the use of purchased seeds might have caused this. It is also worthy to note that the comparison of the plot level analysis to the household level analysis yielded a slightly higher proportion of households using inputs compared to plot proportions. This difference implies that more farm households apply these inputs on their plots, but some households are not applying them on all their plots.

5.2 Household Input Use Consistency

In discussing the second research question, we follow the results section chronologically by assessing the inputs in the same order.

5.2.1 Consistency of Fertiliser Use

Fertilisers are the most used inputs in Nigeria, with moderate consistency; almost 47% of households in the sample used fertilisers at least twice, and more than 25% used them in every wave. The proportions are higher than reported in Akramov (2009) and Sheahan & Barrett (2014) but still similar, especially in being the highest used inputs in Nigeria. For this analysis, using the same households in all three waves allows us to imply from the results that households are not highly consistent in the application of fertilisers. The zonal differences also show that Northern households are more consistent than Southern households, especially for the North West and the South West. The soil quality in the Northern zones could be the main reason for these differences.

5.2.2 Consistency of Herbicide Use

For herbicides, consistency is even lower than for fertilisers, with only 29.9% of households using them at least twice in the three waves. The zonal variations in favour of the North still exist, although the South West has the largest proportion of households that used herbicides. The fertiliser usage in the north corroborates the high use of herbicides since the weeds will have more nutrients to grow(Sheahan & Barrett, 2014). Therefore, the North West should have a high level of herbicide use by this logic. Interestingly they do not and instead have the lowest proportion. This result could be due to other factors such as labour availability and machinery use that could be used as a substitute for weed removal.

5.2.3 Consistency of Pesticide Use

Pesticides use is low, although the North West and the South West have considerably higher proportions than other zones and the national average. The pesticide usage trend is a possible justification for the fertiliser + herbicide relationship expected in the North West but not existent. The moderate application of pesticide implies that households in the North West are either dealing with crops that are more susceptible to pest attacks, or they have alternative ways of dealing with weeds. After all, farmers are efficient, and they will make the best use of their available resources (Sheahan et al., 2013). Households in the South West use pesticides more consistently than every other zone, implying that they deal with more issues requiring agrochemicals and not fertility issues. It could also be that they do not purchase as much improved seeds that might aid in combatting the effect of pests and weeds.

5.2.4 Consistency in the Use of Purchased seeds

The average use of purchased seeds is moderate, and the consistency of usage is relatively low. Although the South East shows impressive results, they use more purchased seeds, and the level of consistency is moderate, with over 50% of households using purchased seeds more than twice in the three waves. This result is supported by the findings of Uduji & Okolo-Obasi (2018). Also, the idea that improved seeds are more resilient and resistant to pest and diseases explains the low use of agrochemicals (herbicides and pesticides) in the South East, especially since soil fertility is higher than in the Northern zones.

5.3 Relationship Between Receiving Credit and Input Use

In the third research question, the analysis of the factors affecting inputs usage yielded many expected results, with the usual zonal differences. For the individual analysis, irrigation was not considered due to the negligible use shown in the first two research questions. It is important to note that the proportion of households with a member that received formal or informal credit for any reason is very low, considering the number of credit-related government interventions Eze et al. (2010). Nonetheless, the low level of credit is supported by previous papers on farmers access to credit in Africa, including Nigeria (Adjognon et al., 2017).

5.3.1 Relationship Between Receiving Credit and Using Fertilisers

The result that receiving credit has no relationship with using fertiliser differs from Adjognon et al. (2017). They found a correlation between households receiving credit and the use of fertilisers. However, this study included interaction terms to assess how receiving credit, and relevant extension relates to using inputs. We see that the interaction term of extension and formal credit is negatively related to using fertiliser. Although this is unexpected, Maiangwa et al. (2010) explained that this type of relationship could be because contact with an extension agent may have led to increased knowledge for farmers on other businesses that the households might consider more lucrative. Therefore, the farmer applies for credit to fund this other business rather than investing in inputs. Crop income being positively related to credit fits into the report of Akpan et al. (2012); Reardon et al. (1999), and many others in that the price of outputs or output value is positively related to the use of fertilisers. Income from non-farm enterprises being positively related is supported by Adjognon et al. (2017). The cash crop considered in the analysis contains more crops than the traditional cash crop considered in Adjognon et al. (2017). They did not find a significant relationship between planting cash crops and food crops. The analysis was carried out with both cash crops classifications, and a significant relationship was found when the definition of cash crops included more crops. This result implies that the definition of cash crops might have been the reason for the statistical non-significance in Adjognon et al. (2017).

The zonal analysis did not show much variation, which was expected as fertilisers are widely used in Nigeria, and the majority of the farmers are rural farmers with similar socio-economic characteristics. It is important to note that the zones' descriptive statistics show that the southern zones received more formal and informal credit than northern zones. The level of inputs used in the North was higher than in the South, where more households received credit. This result confirms that most of the credit goes into non-farm enterprises, as Adjognon et al. (2017) reported.

Intuitively, another reason for credit being unrelated to fertiliser use could be the more common use of fertiliser as a necessity in crop farming. Therefore, households purchase fertilisers regardless of receiving credit or not. Extension service is more important for fertilisers than credit; it has a highly significant positive relationship. The plot size is also not related to the use of fertilisers, similar to Adjognon et al. (2017).

5.3.2 Relationship Between Receiving Credit and Using Herbicides

Nationally, herbicide use is affected by most of the variables, including formal and informal credit. The positive relationship differs from Alabi et al. (2014) results where credit was negatively related to the use of agrochemicals in Gwagwalada and Kuje situated in the North Central. However, the positive relationship nationally is intuitively accurate, although the level of significance of informal credit is low. The differences in Alabi et al. (2014) could be due to the level of analysis. As soon as we look at the zonal differences in the credit effect on herbicides usage, receiving credit is not significant in the North Central and the South East.

However, formal and informal credit interaction terms with extension services were significant with a negative relationship in the North Central, and this is supported by Alabi et al. (2014) and Maiangwa et al. (2010).

The recommendation for herbicides is that policy intervention to increase the use of herbicides should not be made nationally. The national results do not tell the whole story of factors that impact the usage of herbicides. Other income such as grants, gifts and interest income correlate with herbicides usage in the North Central and not income from crop sales as seen in the North West. Results from the southern zones also differ from each other considerably.

5.3.3 Relationship Between Receiving Credit and Using Pesticides

The use of pesticides shows similar variations to herbicide use in zones. Nationally, formal credit being positively related to pesticide usage is intuitive. However, it is surprising that informal credit does not affect pesticides' usage since the main difference here is the source of credit. Consistently, the type of crop has been a factor in the use of inorganic fertilisers and agrochemicals. It implies that planting cash crops is a significant factor in the consideration for input use. An analysis of the benefits of applying these inputs for food crops might show us why. The type of crop (cash crops or food crops) might be more relevant for pesticide application.

5.3.4 Relationship Between Receiving Credit and Using Purchased seeds

Receiving extension services, income from crop sales, and other income are positively related to the use of purchased seeds. This result is intuitive as we expect that financial capabilities affect input use, although only formal credit has a slight correlation with the use of purchased seeds. The majority of the variables found significant by Uduji & Okolo-Obasi (2018) is not significant here. It could be due to the national level of this paper’s analysis, especially since credit is more significant in the North Central, North East, South East. Even though off-farm labour is minimal, there is a positive relationship with the use of purchased seeds. This positive relationship is supported by Adjognon et al. (2017) on tied labour – output arrangements. It is also interesting that the type of crops planted is not relevant to the use of purchased seeds. Additionally, there is a positive relationship between using purchased seeds and being in the urban area; this result is corroborated by the Takeshima & Nagarajan (2015) report that most private dealers in improved seeds are situated in urban areas.

5.3.5 Relationship Between Receiving Complementary inputs use

As expected, almost all the relevant variables for the individual inputs are relevant for joint usage. The only variables that do not affect complementary usage nationally are age, mean annual precipitation and off-farm labour. The zonal differences are still present as reported. The two types of credit are positively related to using more than one type of inputs in a household. The cumulation of factors affecting the usage of these inputs individually is expected to affect joint usage.

5.4 Recommendations and Conclusion

In Conclusion, complementary usage of inputs in Nigeria is low at around 20% of plots for the most paired inputs (herbicides + fertilisers) in the last wave. There is still much to be done in promoting the synergistic use of inputs, as most plots are applied with only fertilisers. It is also imperative to mention that this study only analysed joint usage; ascertaining that farmers are using inputs jointly because of the complementary benefits will require qualitative analysis.

The consistency analysis shows that fertilisers and purchased seeds were used with moderate consistency (47% & 50% of households) by Nigerian farmers in at least two waves. The consistency for the other inputs is considerably lower. The data was collected with gaps between the collection period, and since farming occurs every year, this study might not tell the whole story.

For the relationship between credit and inputs use, we see that depending on the zones, we can either reject or not reject the null hypotheses for all inputs, both individual and complementary use. This result leads to an overarching recommendation that government interventions should be more specific and decentralized to suit local needs and conditions. As seen in the literature, most of the policies affecting credit and inputs use are introduced and applied nationally. There are a few reasons why this approach might not yield the best results, including elite and political capture, inputs unfit for location, and discordance between stakeholders, as discussed by Amurtiya et al. (2018) and Eze et al. (2010). Additionally, this analysis adds to the information on the zonal differences between factors that affect the use of inputs individually and complementarily in Nigeria. We can reject the null hypothesis for individual use of herbicides, pesticides, and purchased seeds on the national level. The only exception is for the use of fertilisers, in which we cannot reject the null hypothesis. The exception leads to the recommendation that increasing extension services, all-round rural development, especially market development and market access, are more critical for fertiliser usage than credit. We also reject the null hypothesis for complementary use, which implies that the government´s focus on making credit more accessible to farmers is in the right direction. Furthermore, it is imperative to recommend focusing on extension services that focus on showcasing the benefit of using inputs synergistically to increase inputs' complementary usage. This recommendation should be implemented together with improving access to credit, market development, and overall rural development that will lift the farmers' socio-economic characteristics.

5.5 Limitations

The complementary and consistency analysis have limited interpretation scalability, as the survey weights were not used in the analysis. It is impossible to confidently back the interpretation of the results as a national statistic. However, there are considerable similarities between the usage proportions reported in papers that applied the weights and interpreted the results as national statistics(Adjognon et al., 2017; Sheahan & Barrett, 2014).

Additionally, the use of purchased seeds as a proxy for improved seeds is still not entirely justified. There is a need to use a more accurate question in the data collection to get information on improved seeds. This paper only looks at the use of these inputs, but it is relevant to also look at the quantity of each input applied to see if complementary use benefits are being fully tapped.

The regression analysis also faces limitations accompanied by assumptions surrounding random-effect analysis. Therefore all interpretations are only correlates and not causal effects. Furthermore, being a quantitative analysis from secondary data, the numbers might point in the directions. However, there is a need for a more in-depth qualitative analysis or additional primary data quantitative analysis to get deeper into the underlying factors affecting these inputs' use.

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Social and Institutional Change in Agricultural Development
Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute)
Universität Hohenheim
Wollgrasweg 43 | 70599 Stuttgart | Deutschland
T +49 (0)711-459-23517 | **F** +49 (0)711-459-23812
E regina.birner@uni-hohenheim.de | https://490c.uni-hohenheim.de/en