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WHICH AGRICULTURAL INNOVATIONS MATTER MOST TO NIGER'S FARMERS? COUNT-BASED AND BEST-WORST SCALING APPROACHES

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ABSTRACT
The negative impact of quadruple insecurities (food, health, security and climate change) on smallholder farmers and their livelihoods have been considered as global challenge and threat for sustainable development and climate change management in most developing nations. Although farmers have developed and keep developing coping strategies by innovating to accommodate the negative impact of this quadruple insecurity, little is relatively known how agricultural innovations and its impact on farmers' welfare in changing climate are poorly understood. Based on previous studies and Survey amongst farmers, twenty four agricultural innovations have identified and included in this research. The experimental design popularly called complete block design was used to collect data from 436 farmers randomly selected. For each question, farmers were asked to choose his eight best and his eight worst agricultural innovations in changing climate. This repeated process is consistent with random utility, which is deeply rooted in microeconomic theory. Count-based method and multinomial logit were used to fit the data. Results indicate that rainfed rice production, saving and credit scheme for rural women, Maradi red goat breeding, processing peanuts into oil and cake, planting trees for land recovering, using of annual and perennial crops for cattle fattening, manufacturing handicrafts with local perennial crops, honey harvesting via improved beehives, cheese making are the most important agricultural innovations that farmers would prefer to implement in changing climate. Income and Animal-based agricultural innovations are more welfare enhancing. The findings of this research may be used to promote and achieve the United Nations sustainable development goals by planning changes and thereby improving the food security and local farmer's welfare in the study area and beyond.

KEY WORDS
Agricultural innovations, farmers, changing climate, conditional logit, complete block design.

Achieving sustainable development goals (SDGs) has been not only eroded by human capacity development and demographic challenges, but also threatened by difficult and unpredictable climatic conditions as well as by the recent COVID-19 pandemic. There are also many complex agricultural production challenges such as infertile soils, low and erratic rainfall regime, floods, drought, lack of adequate market information, low human and socio-economic development making the predominant smallholder farmers face uncertain situations in attempting to intensify food production. Therefore, farmers need to have adequate access to quality extension agent, resources and agricultural innovations to enable them increase productivity thereby enhancing food and income security (Braun et al, 2021). The application of agricultural innovations towards achieving sustainable development goals in African countries such as Niger is poorly understood and documented.

African countries in general and West African countries in particular are expecting considerable contributions from science and technology in the agricultural sector in order to address the significant challenges related to population, economic growth, food security, climate change, poverty reduction (Zoundi & Hitimana, 2005). These challenges have been exacerbated by the covid-19 pandemic negative impact on food sector and agriculture. The pandemic has also stimulated innovative spirits by developing and deploying digital technology thereby addressing these challenges and proposing solutions. Recent studies from Africa suggest that digital technology can enhance smallholder productivity and income by improving their access to farm output, inputs and financial markets. A large body of studies has also revealed that innovation in general and agricultural innovation in particular when properly managed can contribute to achieve sustainable goals. Studies have also indicated that technological and institutional innovations can potentially improve the agricultural productivity, food security and income levels of smallholder men and women farmers. However, innovation processes are hindered by barriers related to governance, the economy, knowledge, socio-cultural factors, and resource factors. Furthermore, transform followers to leaders and leaders to agent of change is key to effectively and efficiently manage limited resources for the benefit of the majority (Haug *et al*., 2021). Digitalization of African agriculture has recently gained momentum with diversity of digital tools, platforms and services emerging and being deployed to support delivery of extension agents to farmers, thereby contributing to reduce rural poverty and improve food security in Africa (Juma, 2011; Gatzweiler & Von Braun, 2016). Finally, understanding and applying these innovations in agriculture thereby achieving United Nations' sustainable development goals is a key challenge.

In Niger, balancing population growth and the food supply constitutes a real challenge especially in countries where agricultural innovations' adoption rate is still very low (Braun *et al*. 2021). There were 32 agricultural innovations that have been characterized, selected and documented, in which 12 innovations in Dioundiou and Yelou, 20 innovations in Torodi and Makalondi (Saidou & Adam, 2013). The objective of this Project is to help farmers to build their resilience capacity in order to enhance food security. This project called Innovation Africa pointed out that food security should be based on the promotion of agricultural innovations and local strategies as well as local planning thereby improving food security situation at rural household level. Participative approach was used to compile the best agricultural innovations and local strategies for food security. Endogenous, exogenous and hybrid agricultural innovations have been disseminated, but in realizing agricultural innovation objectives as a result of the advancement in information and communication technologies (ICT), adequate agricultural information should be provided to farmers. Digital agricultural is also a key to plan and effectively and efficiently manage changes that may occur in the future. In addition,

E-agriculture has been recently developed to improve agricultural and breeding practices for both crops and livestock, facilitate easy access to market and thereby gaining a better benefit for their products (Hamadou, 2018).

In Tahoua State, agricultural innovation such water and soil conservation activities has been undertaken to bring back marginal land in active agricultural production. Thus, Tahoua State has benefited several interventions ranging from Keita integrated project, to low valley projects and small scale irrigation which have been used as strategies to restore degraded ecosystems and thereby ensuring food security. Recent studies have also documented that exogenous, endogenous and hybrid agricultural innovations have been developed and disseminated amongst resource-poor farmers, but agricultural production is still low and the impact of introducing these agricultural innovations on farmers productivity, income, poverty reduction and welfare is poorly understood and documented.

The objective of this paper is to assess farmers' preferences for agricultural innovations. Specific objectives include: (i) to determine the influence of farmers' socioeconomic characteristics on agricultural innovations; (ii) determine the influence of farms' characteristics on agricultural innovations. We hypothesize that crop-based agricultural innovations are more welfare enhancing in animal-based agricultural innovations. We also hypothesize that income generating activities based agricultural innovations are more welfare enhancing than food science and nutrition based agricultural innovations. Finally, we assume than endogenous agricultural innovations are more welfare enhancing than exogenous and hybrid agricultural innovations.

THEORETICAL FRAMEWORK

The farmer immediate environment is dynamically influenced by various changes due to climate change, flood, tornado and famine. Random utility theory that is well rooted in microeconomic has been widely used in studying consumers' behavior. Methods of data collection such as on likert scale as well as Best Worst Scaling (BWS) have well documented in the literature, but methods such as complete block design as data collection is still in its infancy. Extension agents are trained as leaders to facilitate innovations diffusion amongst rural farmers who become agent of change. Farmers adopt a given innovation where he has perceived the intended benefits. Similarly, when a bundle of innovations are presented to farmers, they would make repeated choices amongst the most important, the least important and indifferent bundles.

MATERIALS AND METHODS OF RESEARCH

Experimental design called complete block design was used to design questionnaire served in data collection from randomly selected respondents. The application of this design is based on a simple data generating process which consists of identifying a set having multiple of three baskets. Based on previous studies related to agricultural innovations and Survey with resourceful persons, 24 agricultural innovations have been identified and included in this study. Thus, for each question, each respondent was asked to select his eight best and eight worst agricultural innovations. In total, 436 respondents were randomly selected and interviewed. Data were collected in both rural and urban areas of Tahoua State as a ways to diversify the sample. To determine the relative importance of each agricultural innovation, a BWS experiment design was employed. Table 1 was used to collect data from randomly selected farmers and herdsmen.

Table 1 – Listed below presents a sample of the questionnaire served in data collection

Eight (8) most important agricultural innovations	Agricultural innovations included in the study	Eight (8) least important agricultural innovations
✓	Rainfed rice cultivation	
✓	Land recovering via tree planting	
✓	Maradi red goat breeding	
✓	Women's saving and credit scheme	
✓	Honey harvesting via improved beehives	
	Use of millet glumes in cassava production	
	Cheese making	✓
	Use of cassava for cattle fattening	✓
	Processing peanuts into oil and cake	✓
	Transforming Shea butter in soap	
	Use of annual and perennial crops for cattle fattening	
	Use of semi-modern irrigation system in gardening	
✓	Transforming sorghum in couscous	
✓	Manufacturing handicrafts with local perennial crops	
	Fertilization of land with household debris and waste	✓
	Use of peanut cake for food conservation	
	Production and Marketing of gum Arabic	✓
	Plantation of leguminous crops such Acacia spp	
✓	Production and marketing of *Moringa oleifera*	
	Transforming cassava into bread flour	
	Use of early improved varieties of millet	
	Private development of rivers for rainfed rice cultivation	✓
	Degraded land recovering and fertilization via organic manure	✓
	Growing onions in sandy soil	✓

Source: List of most important agricultural innovations adopted from Saidou and Adam (2013) and used as tools for data collection.

We assumed that the BWS approach based on repeated choices between the most important and the least important agricultural innovations is consistent with random utility theory, which is well rooted in the microeconomic theory. Thus, the utility function for various types of agricultural innovations can be mathematically expressed as follows:

$$U_{ij} = \beta_j - \beta_k + \varepsilon_{ij} \qquad (1)$$

Where: U_{ij} is the utility for person i facing agricultural innovations j, β_j is the utility for person i selecting best agricultural innovations j, β_k is the disutility of per i selecting worst agricultural j and ε_{ij} is the stochastic term which is assumed to be normally distributed with mean zero and variance σ_ε^2. The difference between β_j and β_k is assumed to be normally distributed with mean μ and variance-covariance Ω. The equation (1) is also assumed to mimic the underlying data generating process.

Alternatively, the relative importance can be mathematically written as follows:

$$\mathrm{P_i} = \mu = \frac{\beta_i - W_i}{8N} \qquad (2)$$

Where: $\mathrm{P_i}$ is the weighted average for a given agricultural innovation, β_i is the number of times that a given agricultural innovation was selected the best, W_i is the number of time that a given agricultural innovations was chosen as the worst, N is the sample size and eight (8) is the frequent of selecting a basket of agricultural innovations as best and worst. The standard deviation for various agricultural innovations was computed using information matrix denoted Ω. For instance, the given standard deviation can be mathematically expressed as follows:

$$SD_i = \sqrt{\frac{P_i(1-P_i)}{N}} \qquad (3)$$

Where: SD_i denotes standard deviation for agricultural innovation i, P_i is the relative proportion or probability of a given agricultural innovations, $(1-P_i)$ is the probability that innovation i is not selected and N is the sample size.

RESULTS AND DISCUSSION

This section summarizes information from data analysis. Tables 1 through 6 respectively report socioeconomic characteristics of surveyed farmers, farmers preferences for agricultural innovations, determinants of agricultural innovations and farmers' welfare estimates for agricultural innovations. Table 2 presents the socioeconomics characteristics of surveyed respondents.

Table 2 – Socioeconomic characteristics of surveyed respondents

Variables	Definitions	Mean	SD
Age	Age in numbers	30	10.000
Gender	1 for male, 0 otherwise	0.62	0.486
Marital status	1 for married, 0 for non married	0.67	0.470
Education	1 for educated, 0 otherwise	0.80	0.400
Annual income	1 if income between 51000 and 80000, 0 otherwise	0.26	0.250
	1 if income greater than 80000, 0 otherwise	0.44	0.434
Annual expenses	1 if expenses between 26000 and 40000, 0 otherwise	0.13	0.083
	1 if expenses greater than 40000, 0 otherwise	0.34	0.276
Food security	1 if yes food secured household, 0 for no	0.31	0.461
Family Size	1 for family size greater 7, for family size less than 7	0.47	0.500
Farm size (ha)	1 for farm size greater than 10 ha, 0 for less than 10 ha	0.31	0.461
Herd size (head)	1 for herd Size greater than 20, 0 for herd size less than 20	0.47	0.500
N		436	

As reported in Table 2, most of respondents were male (62%), married (67%), educated (80%), and with an average age of 30 years. While majority of respondents (70%) had an annual income between 51000 to 80000 and above 80000, 53% of respondents were planned to spend their income less than 26000 on agricultural innovations. Most of respondents (69%) would prefer to adopt agricultural innovations for reasons rather than food security. Finally, most of respondents had 53%, 69% and 53% respectively for family size less than 7 members, farm size less than 10 ha and herd size less than 20 heads.

Table 3 presents farmers preferences for agricultural innovations based on count-based estimates. As indicated in Table 3, coefficients with positive signs are considered as the most important, while coefficients with negative are considered as least important. Results show that rainfed rice cultivation, women's saving and credit scheme, honey harvesting via improved beehives, use of millet glumes in cassava production, Maradi red goat breeding, planting trees for land recovering, processing peanuts into oil and cake, use of semi-modern irrigation system in gardening, use of annual and perennial crops for cattle fattening, manufacturing handicrafts with local perennial crops and cheese making are positive and significant at 5% level, revealing that these agricultural innovations are the most important for farmers. This is consistent with a study on effect of zai and water conservation technique on water balance conducted in Niger shows that this system improves soil water status allowing plants to escape from dry spells, but leading to loss of nutrients such as nitrogen (Fatondji et al., 2011). Conversely, results indicate that coefficients of transforming cassava into bread flour followed by the use of early improved varieties of millet, private development of rivers for rainfed rice cultivation, degraded land recovering and fertilization via organic manure, planting of leguminous crops such Acacia spp and growing onions in sandy soil are negative and significant agricultural innovations, indicating that they are the least important agricultural innovations for farmers. Results reported respectively in Table 3 and Table 7 shows that count-based and multinomial logit estimation are similar, though multinomial logit estimates are higher in magnitude than count based estimates. Although estimates from both count- based and multinomial estimates being reported, only estimates from the former were presented and interpreted.

Table 3 – Farmers' Preferences for Agricultural innovations based on Best Worst Scaling

Agricultural Innovations identified and included in this study	Best	Worst	Weight $\pm$ SD
Rainfed rice cultivation	165	73	0.038 ± 0.007^a
Women's saving and credit scheme	132	78	0.025 ± 0.006^a
Honey harvesting via improved beehives	136	96	0.017 ± 0.006^a
Use of millet glumes in cassava production	136	96	0.015 ± 0.006^a
Maradi red goat breeding	133	98	0.015 ± 0.006^a
Planting trees for land recovering	123	91	0.014 ± 0.005^a
Processing peanuts into oil and cake	110	79	0.013 ± 0.005^a
Use of semi-modern irrigation system in gardening	125	100	0.012 ± 0.005^a
Use of annual and perennial crops for cattle fattening	121	97	0.011 ± 0.005^a
Manufacturing handicrafts with local perennial crops	120	99	0.010 ± 0.004^a
Cheese making	109	92	0.007 ± 0.002^a
Transforming shea butter in soap	106	95	0.003 ± 0.002
Use of peanut cake for food conservation	107	109	-0.002 ± 0.002
Production and marketing of gum arabic	107	111	-0.003 ± 0.003
Use of cassava for cattle fattening	85	95	-0.005 ± 0.004
Fertilization of land with household debris and waste	99	112	-0.008 ± 0.005
Transforming sorghum in couscous	79	104	-0.011 ± 0.005
Production and marketing of Moringa oleifera	63	89	-0.013 ± 0.006
Transforming cassava into bread flour	48	88	-0.018 ± 0.007^a
Use of early improved varieties of millet	66	108	-0.019 ± 0.007^a
Private development of rivers for rainfed rice cultivation	57	103	-0.020 ± 0.007^a
Degraded land recovering and fertilization via organic manure	69	123	-0.021 ± 0.007^a
Planting of leguminous crops such Acacia species (spp)	70	125	-0.022 ± 0.009^a
Growing onions in sandy soil	56	140	-0.035 ± 0.001^a
N	436		-

Note: Weight $\pm$ SD stands for weighted average and standard deviation respectively. Numbers with letters are significantly different at 5% level. These agricultural innovations were first documented by Saidou and Adam (2013).

With regard to education, results show that educated farmers prefer rainfed rice cultivation and land recovering via tree planting as their best agricultural innovations, whereas uneducated farmers prefer degraded land recovering and fertilization via organic manure. Table 4 reports determinants of agricultural innovations. Results presented in Table 4 report the determinants of agricultural innovations as function of gender, marital status, educational level and age.

With regard to gender, Table 4 shows those male header households prefer rainfed rice cultivation followed by land recovering via tree planting. Maradi red goat breeding, women's saving and credit scheme, honey harvesting via improved beehives and use of millet glumes in cassava production as their best agricultural innovations to be implemented; while female headed household would prefer to implement agricultural innovations such as transforming cassava into bread flour followed by the use of early improved varieties of millet, private development of rivers for rainfed rice cultivation, degraded land recovering and fertilization via organic manure, planting of leguminous crops such Acacia species and growing onions in sandy soil.

With respect to marital status, results reveal that married farmers would prefer to implement agricultural innovations such as rainfed rice cultivation, women's saving and credit scheme, honey harvesting via improved beehives, use of millet glumes in cassava production, Maradi red goat breeding, planting trees for land recovering, processing peanuts into oil and cake, use of semi-modern irrigation system in gardening, use of annual and perennial crops for cattle fattening, manufacturing handicrafts with local perennial crops and cheese making. In contrast, non married farmers would prefer to vote for production and marketing of gum arabic, use of cassava for cattle fattening, fertilization of land with household debris and waste, transforming sorghum in couscous, production and marketing of *Moringa oleifera,* transforming cassava into bread flour, use of early improved varieties of millet, private development of rivers for rainfed rice cultivation, degraded land recovering and fertilization via organic manure, planting of leguminous crops such Acacia spp and growing onions in sandy soil as their best agricultural innovations.

Table 4 – Influence of farmers' socioeconomic characteristics on agricultural innovations' preferences

n/n	Male farmers	Married	Education	Young
Agricultural innovations	Weight $\pm SD$	Weight $\pm SD$	Weight $\pm SD$	Weight $\pm SD$
Rainfed rice cultivation	0.036±0.011[a]	0.040±0.011[a]	0.039±0.017[a]	0.040±0.010[a]
Land recovering via tree planting	0.022±0.009[a]	0.023 ±0.009[a]	0.029±0.015[a]	0.030±0.009[a]
Maradi red goat breeding	0.021±0.009[a]	0.022 ±0.009[a]	0.028± 0.015	0.021±0.007[a]
Women's saving and credit scheme	0.020±0.008[a]	0.019 ±0.008[a]	0.022± 0.013	0.020±0.007[a]
Honey harvesting via improved beehives	0.017± 0.008[a]	0.017±0.008[a]	0.022± 0.013	0.018±0.007[a]
Use of millet glumes in cassava production	0.015±0.007[a]	0.015±0.007[a]	0.020± 0.013	0.015±0.006[a]
Cheese making	0.013±0.007	0.012 ±0.006[a]	0.017± 0.012	0.015±0.006[a]
Use of cassava for cattle fattening	0.012±0.006	0.012± 0.006	0.014±0.011	0.015±0.006[a]
Processing peanuts into oil and cake	0.005± 0.004	0.010 ±0.006	0.005±0.006	0.014±0.006[a]
Transforming shea butter in soap	0.003±0.003	0.006 ±0.004	0.005±0.006	0.014±0.006[a]
Use of annual and perennial crops for cattle fattening	0.002±0.003	0.003±0.003	0.004±0.006	0.004±0.003
Use of semi-modern irrigation system in gardening	0.002±0.003	0.000±0.001	0.004±0.006	0.004±0.003
Transforming sorghum in couscous	0.002±0.003	0.000 ±0.001	0.001±0.003	-0.002±0.002
Manufacturing handicrafts with local perennial crops	-0.004±0.004	-0.003 ±0.003	0.001±0.003	-0.003±0.003
Fertilization of land with household debris and waste	-0.005±0.004	-0.005 ±0.004	-0.003±0.005	-0.008±0.005
Use of peanut cake for food conservation	-0.006±0.005	-0.005 ±0.004	-0.008± 0.008	-0.010±0.005
Production and marketing of gum arabic	-0.012±0.007	-0.015 ±0.007[a]	-0.009±0.009	-0.014±0.006[a]
Plantation of leguminous crops such acacia spp	-0.015±0.007	-0.015 ±0.007[a]	-0.012±0.010	-0.018±0.007[a]
Production and marketing of Moringa oleifera	-0.015±0.008	-0.018±0.008[a]	-0.022±0.014	-0.018±0.007[a]
Transforming cassava into bread flour	-0.017 ±0.008[a]	-0.020±0.008[a]	-0.022 ± 0.014	-0.021±0.008[a]
Use of early improved varieties of millet	-0.018 ±0.008[a]	-0.020± 0.008[a]	-0.026±0.015	-0.021±0.008[a]
Private development of rivers for rainfed rice cultivation	-0.019± 0.008[a]	-0.020 ±0.008[a]	-0.031±0.016	-0.023±0.008[a]
Degraded land recovering and fertilization via organic manure	-0.020 ± 0.009[a]	-0.023± 0.009[a]	-0.036±0.017[a]	-0.027±0.009[a]
Growing onions in sandy soil	-0.032± 0.011[a]	-0.030±0.010[a]	-0.043±0.019[a]	-0.037±0.010[a]
N	271	291	124	371

Note: Weight ± SD stands for weighted mean and standard deviation, note that numbers with letters are significantly different at 5% level.

Finally, with regard to age, results show that coefficients of rainfed rice cultivation followed by land recovering via tree planting, Maradi red goat breeding, women's saving and credit scheme, honey harvesting via improved beehives, use of millet glumes in cassava production, cheese making, use of cassava for cattle fattening, processing peanuts into oil and cake and Transforming shea butter in soap were positive and significant, revealing that young farmers prefer to implement these agricultural innovations. Conversely, coefficients of production and Marketing of gum arabic followed by plantation of leguminous crops such Acacia spp, gardening and marketing of Moringa oleifera, transforming cassava into bread flour, use of early improved varieties of millet, private development of rivers for rainfed rice cultivation, degraded land recovering and fertilization via organic manure and growing onions in sandy soil were negative and significant, showing that old farmers prefer to implement these agricultural innovations.

Table 5 reports influence of farm characteristics such as family size, farm size, herd size and food security information on farmers' agricultural innovations preferences. Results indicate that coefficients for rainfed rice cultivation, land recovering via tree planting, Maradi red goat breeding, women's saving and credit scheme and honey harvesting via improved beehives were positive and significant at 5%, implying that these agricultural innovations are the most important for large family size. However, coefficients of use of early improved varieties of millet followed by private development of rivers for rainfed rice cultivation, degraded land recovering and fertilization via organic manure and growing onions in sandy soil are the most important agricultural innovations for Small family size.

When food security information is provided, results show that rainfed rice cultivation, land recovering via tree planting, Maradi red goat breeding, Women's saving and credit scheme, honey harvesting via improved beehives and use of millet glumes in cassava production were the most important agricultural innovations to cope with food security. However, when food security information is not provided, results indicate that use of early improved varieties of millet followed by private development of rivers for rainfed rice cultivation, degraded land recovering and fertilization via organic manure growing onions in sandy soil as their most valuable agricultural innovations.

Table 5 also presents the influence of herd size on agricultural innovations adoption. Results show that farmers with large herd size prefer to adopt rainfed rice cultivation followed by land recovering via tree planting, Maradi red goat breeding, women's saving and credit scheme, honey harvesting via improved beehives as their best agricultural innovations. Results also reveal that farmers with small herd size prefer to implement private development of rivers for rainfed rice cultivation, degraded land recovering and fertilization via organic manure growing onions in sandy soil as their best agricultural innovations.

Table 5 – Influence of farm's characteristics on agricultural innovations' preferences

n/n	Large family size	Large farm size	Food security	Large livestock size
Agricultural innovations	Weight $\pm SD$	Weight $\pm SD$	Weight $\pm SD$	Weight $\pm SD$
Rainfed rice cultivation	0.034±0.013[a]	0.029±0.016	0.038±0.011[a]	0.048±0.015[a]
Land recovering via tree planting	0.028±0.012[a]	0.020±0.013	0.0200±0.008[a]	0.035±0.013[a]
Maradi red goat breeding	0.018±0.009[a]	0.019±0.013	0.020±0.008[a]	0.028±0.011[a]
Women's saving and credit scheme	0.018±0.009[a]	0.018±0.012	0.020±0.008[a]	0.023±0.011[a]
Honey harvesting via improved beehives	0.018±0.009[a]	0.015±0.012	0.019±0.008[a]	0.020±0.010[a]
Use of millet glumes in cassava production	0.016±0.009	0.013±0.011	0.015±0.007[a]	0.014±0.008
Cheese making	0.016±0.009	0.012±0.010	0.012±0.007	0.013±0.008
Use of cassava for cattle fattening	0.014±0.008	0.010±0.009	0.009±0.006	0.009±0.007
Processing peanuts into oil and cake	0.013±0.008	0.007±0.008	0.008±0.005	0.006±0.005
Transforming shea butter in soap	0.011±0.007	0.007±0.008	0.006±0.005	0.002±0.003
Use of annual and perennial crops for cattle fattening	0.010±0.007	0.004±0.006	0.003±0.003	0.001±0.002
Use of semi-modern irrigation system in gardening	0.000±0.000	0.003±0.005	0.002±0.003	0.001±0.002
Transforming sorghum in couscous	-0.002±0.003	0.001±0.003	0.000±0.001	0.000±0.000
Manufacturing handicrafts with local perennial crops	-0.002±0.003	-0.003±0.005	-0.001±0.002	-0.003±0.004
Fertilization of land with household debris and waste	-0.010±0.007	-0.006±0.007	-0.006±0.005	-0.004±0.005
Use of peanut cake for food conservation	-0.010±0.007	-0.007±0.008	-0.008±0.005	-0.005±0.005
Production and Marketing of gum arabic	-0.011±0.007	-0.008±0.008	-0.009±0.006	-0.009±0.007
Plantation of leguminous crops such acacia spp	-0.012±0.008	-0.010±0.009	-0.012±0.007	-0.014±0.008
Production and marketing of *Moringa oleifera*	-0.013±0.008	-0.014±0.011	-0.014±0.007	-0.016±0.009
Transforming cassava into bread flour	-0.016±0.009	-0.017±0.012	-0.014±0.007	-0.017±0.009
Use of early improved varieties of millet	-0.021±0.010[a]	-0.019±0.013	-0.015±0.008[a]	-0.019±0.010
Private development of rivers for rainfed rice cultivation	-0.022±0.011[a]	-0.022±0.014	-0.020±0.009[a]	-0.032±0.013[a]
Degraded land recovering and fertilization via organic manure	-0.023±0.011[a]	-0.023±0.015	-0.025±0.010[a]	-0.036±0.013[a]
Growing onions in sandy soil	-0.040±0.014[a]	-0.034±0.018	-0.035±0.012[a]	-0.048±0.016[a]
N	204	113	276	204

Table 6 represents various type values of agricultural innovations as function of farmers socioeconomic and farm characteristics. Results reveal that farmers place higher value on income generating activities based agricultural innovations (0.645) followed by animal-based agricultural innovations(0.456), implying that farmers place higher values on income generating activities and animal-based agricultural innovations. Results indicate that farmers' value for animal-based agricultural innovations (0.456) is higher than those for crop-based agricultural innovations(-0.305), implying that hypothesis stating that crop-based agricultural innovations are higher than animal-based agricultural innovations was rejected and concluding that animal-based innovations are more welfare enhancing than crop-based innovations. Results also suggest that farmers' value for income based agricultural innovations (0.645) is higher than food science and nutrition based agricultural innovations (-0.032).

Table 6 – Values of agricultural innovations as function of farmers characteristics

Farmers' characteristics	Crop- based	Animal-based	Food Science and nutrition	Natural Resource management	Income generating activities
Male	-0.046	0.024	0.015	-0.004	0.004
Female	-0.023	0.032	-0.036	-0.031	0.066
Married	-0.049	0.015	0.007	0.004	0.002
Non married	-0.030	0.030	-0.005	-0.062	0.046
Instruct	-0.029	0.024	-0.029	0.018	0.042
Non instruct	-0.011	0.037	0.015	-0.022	0.037
High income	-0.011	-0.001	0.015	0.015	0.019
Medium income	-0.015	0.012	0.023	-0.030	0.042
High expenses	-0.021	0.101	-0.028	0.017	0.080
Medium expenses	0.031	0.022	-0.009	0.002	-0.057
Small family size	-0.039	0.027	-0.016	0.013	0.048
Large family size	-0.032	0.016	0.015	-0.045	0.085
Small farm size	-0.018	0.015	-0.009	-0.005	0.048
Large farm size	0.008	0.062	0.006	-0.035	0.070
Small livestock size	-0.009	0.047	-0.014	-0.005	0.038
Large livestock Size	-0.009	-0.006	0.018	-0.025	0.078
Total	-0.305	0.456	-0.032	-0.192	0.649

Table 7 – Farmers Preferences based Multinomial Estimates for Agricultural Innovations

Agricultural Innovations	Mnl estimates
Rainfed rice cultivation	0.815* (0.099)
Land recovering via tree planting	0.526* (0.101)
Maradi red goat breeding	0.348* (0.094)
Women's saving and credit scheme	0.348* (0.094)
Honey harvesting via improved beehives	0.305* (0.094)
Use of millet glumes in cassava production	0.301* (0.098)
Cheese making	0.331* (0.104)
Use of cassava for cattle fattening	0.223* (0.095)
Processing peanuts into oil and cake	0.221* (0.096)
Transforming shea butter in soap	0.192* (0.096)
Use of annual and perennial crops for cattle fattening	0.170* (0.100)
Use of semi-modern irrigation system in gardening	0.110* (0.100)
Transforming sorghum in couscous	-0.019 (0.096)
Manufacturing handicrafts with local perennial crops	-0.037 (0.096)
Fertilization of land with household debris and waste	-0.111 (0.106)
Use of peanut cake for food conservation	-0.123 (0.098)
Production and marketing of gum arabic	-0.275 (0.106)
Plantation of leguminous crops such acacia spp	-0.346* (0.116)
Production and marketing of Moringa oleifera	-0.606* (0.127)
Transforming cassava into bread flour	-0.492* (0.110)
Use of early improved varieties of millet	-0.592* (0.117)
Private development of rivers for rainfed rice cultivation	-0.578* (0.106)
Degraded land recovering and fertilization via organic manure	-0.580* (0.106)
Growing onions in sandy soil	-0.916* (0.112)
N	432

*Note: Numbers in parentheses are standard errors, * stands for 5% level significance, Mnl stands for multinomial logit.*

Results also suggest that exogenous agricultural innovations (0.034) are higher than endogenous (-0.001) and hybrid (-0.009) agricultural innovations, implying that exogenous innovations would enhancing farmers welfare. This shows that our research hypothesis stating that income based agricultural innovations are higher than food science and nutrition based innovations was not rejected, revealing that income based innovations are more welfare enhancing. These results are not similar with a recent study stating that crop-based food values are higher than animal based food values (Amadou, 2021).

Table 8 – The most important agricultural Innovations identified and included in the study

Agricultural Innovations	Descriptions
Rainfed rice cultivation	It is an exogenous innovation introduced by a development project called JALDA in 2005
Planting trees for land recovering	It is a hydrid innovation initiated by JALDA project in 2004
Use of cassava for cattle fattening	It is an endogenous innovation developed by a 70-year-old farmer
Use of peanut cake for food conservation	It is an endogenous innovation developed by a 55-year-old farmer
Women's saving and credit scheme	It is an endogenous innovation started in 1992 by a group of 40 women
Maradi red goat breeding	It is an endogenous innovation started by a cooperative called CERNAFA in 2010
Use of millet glumes and Piliostigma reticulata for cattle fattening	It is an endogenous innovation aims at combining millet glumes and P. reticulata in 2007
Plantation of leguminous crops such Acacia spp	It is an exogenous innovation started by Peace Corps in 1983
Manufacturing handicrafts with local perennial crops	It is an endogenous innovation started in 1992
Use of millet glumes in cassava production	It is an endogenous innovation developed by a 67-year-old farmer in 2006
Cheese making	It is an endogenous innovation started by female cooperatives in 2000
Production and Marketing of Gum Arabic	It is a hybrid innovation initiated by GESFORM in 2009
Transforming Shea butter in soap	It is an exogenous innovation developed by CECI project in 2006
Honey harvesting via improved beehives	It is an endogenous innovation started in 2008
Degraded land recovering and fertilization via organic manure	It is a hybrid innovation developed by PROLINNOVA project in 1992
Transforming sorghum in couscous	It is an endogenous innovation developed by a 44-year-old female in 2007
Fertilization of land with household waste	It is an endogenous innovation developed by a 48-year-old farmer in 2010
Growing onions in sandy soil	It is an endogenous innovation jointly developed by female farmers and a teacher in 2001
Private development of rivers for rainfed rice cultivation	It is an endogenous innovation developed by local farmer in 2009
Transforming cassava into bread flour	It is an endogenous innovation introduced by a 55-year-old farmer in 1973
Processing peanuts into oil and cake	It is an endogenous innovation initiated by a 46-year-old farmer
Production and marketing of *Moringa oleifera*	It is an endogenous innovation developed by a butcher that is not socially appreciated in 2008
Use of early improved varieties of millet	It is an exogenous innovation introduced by development project in 2007
Use of semi-modern irrigation system in gardening	It is an exogenous innovation introduced by Niger association of private Irrigation in 2007

Note: Agricultural innovations compiled and included in previous studies conducted by Saidou and Adam (2013).

Crop based agricultural innovations: Rainfed rice cultivation, use of millet glumes in cassava production, production and marketing of Moringa oleifera, use of millet glumes in cassava production, use of early improved varieties of millet, growing onions in sandy soil, use of semi-modern irrigation system in gardening and private development of rivers for rainfed rice cultivation.

Animal based agricultural innovations: Maradi red goat breeding, use of cassava for cattle fattening and use of annual and perennial crops for cattle fattening.

Food Science and nutrition based agricultural innovations: Cheese making, transforming sorghum in couscous, transforming cassava into bread flour, and use of peanut cake for food conservation.

Income generating activities based agricultural innovations: Honey harvesting via improved beehives, production and marketing of gum arabic, transforming shea butter in soap and women's saving and credit scheme.

CONCLUSION

Farmers and herdsmen are constantly operating within a vicious although endogenous, exogenous and hybrid innovations have been developed and diffused to address challenges such as climate change, covid-19, food security and poverty reduction. The objective of this paper is to assess farmers' value for agricultural innovations. While complete block design having 24 agricultural innovations was used to collect data from 436 farmers, the count-based method was used to analyze data. For each question, respondents were asked to choose his eight most important and his eight least important agricultural innovations. The difference between the most important and least important agricultural innovations is assumed to be consistent with random utility theory, which is well rooted in microeconomic theory.

Results show that majority of respondents were married male with a formal education. Results suggest that farmers place higher value on agricultural innovations such as rainfed rice cultivation, women's saving and credit scheme, honey harvesting via improved beehives, use of millet glumes in cassava production, Maradi red goat breeding, planting trees for land recovering, processing peanuts into oil and cake, use of semi-modern irrigation system in gardening, use of annual and perennial crops for cattle fattening, manufacturing handicrafts with local perennial crops and cheese making, implying that agricultural extension worker should target and disseminate these technologies thereby boosting production and reducing food security.

Results also suggest that socioeconomics characteristics of farmers such male farmers versus female, married farmers versus non married farmers, educated versus non farmers and young and old farmers are key to disseminate agricultural innovations thereby managing efficiently and effectively these innovations. Results also reveal that farmers characteristics such as large versus small farm size, large versus small family size, food security information and large versus small livestock size greatly influence agricultural innovations amongst farmers.

Results also reveal that animal-based and income-based agricultural innovations should be targeted and reinforced to improve farmers' welfare. These findings may be useful as baseline information that can be used by extension agents to successfully implement agricultural innovations towards achieving sustainable development goals in the study area and beyond. Future direction for research is to study the stability of these agricultural innovations overtime in order to forecast demand indexes and develop a machine learning technique for urban and rural farmers.

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