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ARTICLES

- Preliminary screening of the effect of biochar properties and soil incorporation rate on lettuce growth to guide research and educate the public through extension** 1
B. Hunter, G. E. Cardon, S. Olsen, D.G. Alston and D. McAvoy
- Employment Prospects for Agricultural Graduates in Guinea Conakry** 5
Ismail Ouraich, Jess Lowenberg-Deboer, Alseny Soumah and Diawo Diallo

Full Length Research Paper

Preliminary screening of the effect of biochar properties and soil incorporation rate on lettuce growth to guide research and educate the public through extension

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Extension service of the land grant university system is often the first source of public information for emerging soil amendments such as biochar. Biochar is a charcoal product made by heating plant biomass via pyrolysis and is increasingly marketed as an organic soil amendment. As energy-producing pyrolysis industries expand, there is increasing opportunity to utilize locally produced biochar for its potential value in sustainable agriculture. However, the highly variable properties of biochar materials and their effects on plant growth and soil nutrient supply make it difficult to objectively study the effect of this soil amendment and provide guidance to users of locally sourced biochar materials. Therefore, preliminary screening studies are needed to identify potentially beneficial ranges of biochar properties and their effects on soils and plants that can then be rigorously tested in field research. The role of extension in conducting such screening studies is invaluable to providing both guidance to researchers in developing sound study methods, and in educating the public on biochar and the myriad of uncertainties surrounding its use; thereby establishing the need for rigorous research on its properties. In 2014, a simple, yet informative screening trial was performed to identify optimal biochar pyrolysis production temperature, conditioning (that is, degree of crushing) and soil application rate for future field experiments. Lettuce (*Lactuca sativa*, var. Parris Island Cos) chosen for its short growth period and rapid biomass development, was grown in 9-L pots filled with silt loam field soil amended with biochar and/or fertilizer (or none) made from Utah-sourced cherry wood. The pots were uniformly drip irrigated once daily to keep them near field capacity throughout the study period, thereby eliminating any influence of differential soil-plant-water relations. Three biochar products created from the same cherry wood source, but resulting from three different pyrolysis temperatures (375, 475 and 575°C) and either powder ground (P) or masticated (M) texture were applied to soil at three application rates (1, 2 and 3% by weight). Variation in plant dry weight at harvest within and among treatments was high. Lettuce growth with the addition of biochar was decreased as compared to control treatments in all cases, except for biochar produced at the lowest temperature, 375°C. Results indicate that masticated biochar produced at 375°C and applied to soil at the rate of 2% by mass offers the best combination of beneficial response and ease of handling for future field evaluations. This case study's benefit for demonstrating the value of preliminary screening trials to inform both future research and public outreach education is discussed.

Key words: Biochar, soil amendments, pyrolysis, plant growth, high temperatures.

INTRODUCTION

Biochar is a charcoal product created through the pyrolysis process which heats plant biomass in a closed system at high temperatures and under a limited supply of oxygen to produce combustible gases and oils for energy generation and biochemical manufacturing. Biochar may be applied to the soil as a means for soil carbon enrichment and long-term carbon storage, where it can require from 4 to over 100 years to degrade. This property of biochar makes it a desirable amendment because it does not require annual application. The use of soil-applied biochar in agricultural crops has gained interest in recent years because it has been shown to significantly improve soil tilth, nutrient retention and availability to plants, water holding capacity, and soil aggregate stability (Glaser et al., 2002). Biochar has little nutrient value, but biochar properties allow it to retain existing nutrients in the soil. Reported increases in crop yields with biochar amendment may be attributed to an increase in nutrient availability (Khodadad et al., 2011). Biochar application can also stimulate plant resistance to soil borne diseases through promotion of mycorrhizal fungi and soil microbial populations (Steiner et al., 2008).

Despite the literature citing beneficial effects of biochar, these effects have varied among soil types, biochar production practices and application rates. Few studies have evaluated biochar in arid and alkaline soils (Spokas et al, 2012). One study of biochar application in alkaline soils found that biochar had a delayed positive effect on lettuce growth after an initial two to three months of production where growth was stunted. The same study found the initial negative effect was less prevalent for Bermuda grass, especially when subjected to drought stress. Following one month without irrigation, Bermuda grass with a 2 and 4% concentration of biochar in the soil had 50 and 100% recovery, respectively, as compared to an untreated control (Artiola et al., 2012).

While recent reports on the benefits of biochar have stimulated interest among local growers, it is difficult to piece together results from variable studies to produce general recommendations. Also, the cost of biochar varies widely between sources. Growers in the western USA intermountain region need locally-relevant information to help them evaluate whether biochar could be a viable option for their industry. Biochar production and use does extend beyond agriculture, as a part of a larger sustainable system promoting waste management, fossil fuel energy alternatives, and carbon sequestration. Thus, adoption of biochar by commercial growers as a soil improvement technique could promote the growth of green energy technology and job creation. Study findings

will be relevant to locations beyond Utah, particularly in the Intermountain West, with similar soils and growing conditions.

The objectives of this study were to 1) screen potential treatment combinations to identify a formational pyrolysis temperature and appropriate soil application rate for producing and utilizing biochar in subsequent vegetable production studies, and 2) generate preliminary scientific data useful in extension public education efforts to illustrate the effect of biochar on vegetable growth.

MATERIALS AND METHODS

The biochar used in this study was made by Western Renewable Technologies (WRT) in Linden, Utah from cherry wood sourced from a cooperating fruit grower within 50 km of the facility. The biochar was separated into thirds and each amount processed at a different temperature: 375, 475 and 575°C for 10, 7, or 4 min, respectively. The pyrolysis machine was manufactured by Biogreen® and operated by WRT. After pyrolysis, half of the biomass produced at each temperature was masticated to 0.6 cm size pieces and half was pulverized to a fine powder. Major (2010) indicates that the ideal biochar particle sizes to improve soil moisture retention have not been determined. Borchard et al. (2012) found in a greenhouse experiment with Italian ryegrass that the influence of biochar particle size on nutrient content in soil and biomass was relatively small. The six biochar products (3 temperatures × 2 particle sizes) were applied to silt loam field soil (pH 7.3) in pots at three different rates: 1, 2 and 3% by mass. Fertilizer (see description below) was uniformly added to all pots resulting in 18 biochar treatments. Two control treatments were included: fertilizer only (no biochar) and soil-only (no biochar or fertilizer) for a total of 20 treatments. Three replicates of each treatment were planted for a total of 60 pots.

Before application, biochar samples were weighed and then soaked in water for two weeks with 0.8 g 4-4-4 organic fertilizer (Jobe's®) per pot. Soaked biochar and fertilizer were mixed into silt loam field soil in a large bin, and transferred to #3 nursery pots (9 liters). Automated irrigation was applied for one minute daily with micro bubblers in each pot.

Lettuce (*Lactuca sativa*, var. Parris Island Cos) was seeded on July 11, 2014 and pots were placed on the gravel covered ground of a Cravo® retractable roof greenhouse. The pots were uniformly drip irrigated once daily to keep them near field capacity throughout the study period, thereby eliminating any influence of differential soil-plant-water relations. Plants were thinned to three plants per pot after three weeks, and harvested 90 days after planting. Average plant weight per pot was recorded and used for data analysis. An average weight for each treatment is shown in Figure 1. The variability of weights between replicate pots is expressed as the standard error.

RESULTS AND DISCUSSION

Lettuce growth in the biochar treatment produced at 375°C and pulverized to a fine powder (375P) was the

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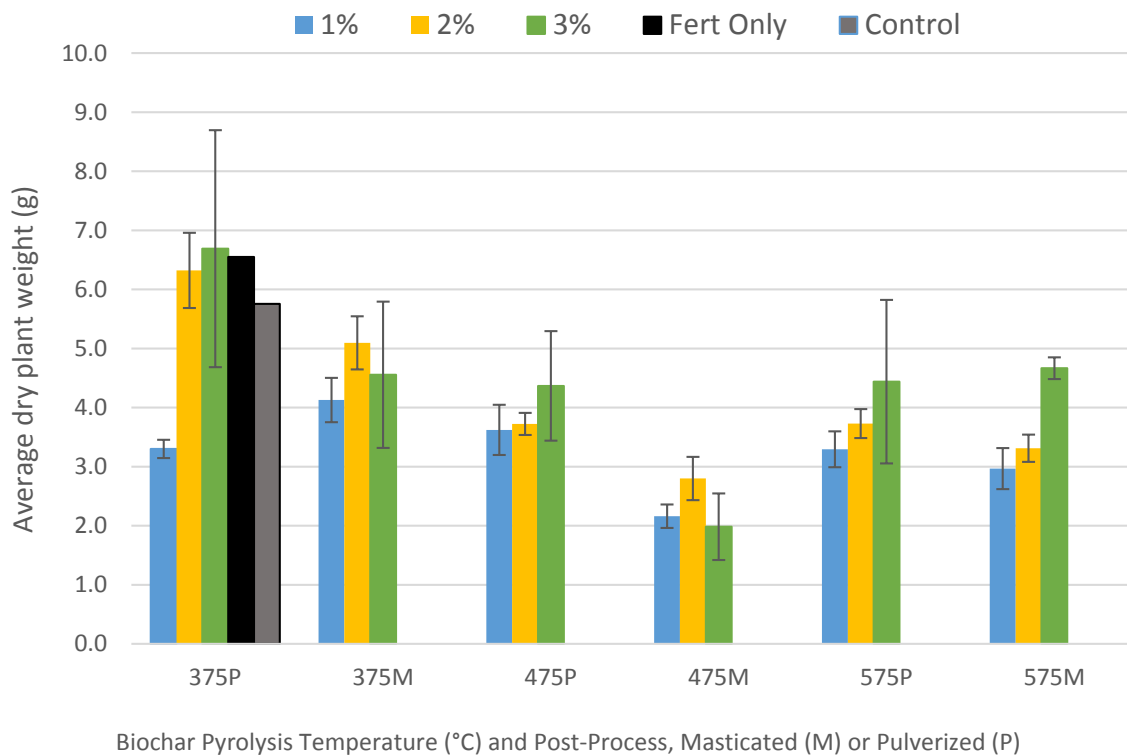


Figure 1. Effect of biochar rate, pyrolysis temperature and particle size on lettuce dry weight per plant. The vertical bars with caps represent standard error (SE).

only treatment to exceed that of the fertilized and unfertilized controls, but only at the 2 and 3% mass-based application rates (Figure 1). Despite its enhancement of plant growth, 375P biochar was difficult to work with due to air drift and hydrophobic properties, making it a much less desirable option for large-scale soil application. The 375°C masticated (375M) biochar, which does not have the drift or hydrophobic properties of 375P biochar, produced lower but statistically similar plant weights to the 375P biochar and performed consistently higher than biochar produced at higher temperatures, regardless of soil application rate. Therefore, the 375M biochar at the 2% mass-based application rate presented the best combination of experimental plant growth effect and ease of handling. Moreover, the biochar formational temperature of 375°C is desirable because of higher biochar yield relative to wood biomass processed and, therefore, higher long-term soil carbon storage potential using this type of biochar.

Greenhouse study

At all temperature treatments, the masticated biochar produced lower plant weights than the pulverized biochar and only one treatment exceeded plant growth above the control. This observation is consistent with a previous

study that reported delayed positive response on lettuce growth of two to three months after biochar application (Artiola et al., 2012). Jay et al. (2015) also notes that biochar may have little or no effect on already productive soils, particularly in the first cropping season after application.

Based on the study results, it was determined that the masticated biochar produced at 375°C would be the best choice for future field evaluations and that it should be applied to the soil at a rate of 2% by mass. It was felt that this rate would have the least likelihood of short-term detrimental effects on plant growth and that the masticated biochar had the most convenient handling characteristics for distribution and soil mixing. Studies are currently underway using this result to guide evaluation of biochar in field tomato and melon production settings in Utah.

Value of the study to extension education

The greenhouse study captured an illustrative range of the effect of biochar produced at various formational temperatures and applied to soil at varying rates. The overall range of response and the observed variability within any given treatment are consistent with previous research and provide an effective educational tool in a

simple graphical summary.

A hypothetical example of the value of the extension information shown in Figure 1 is as follows: A small, struggling organic vegetable producer is interested in using biochar as a soil amendment to increase soil organic matter, improve soil tilth and water relations, and wants to know what they should be aware of when seeking an appropriate biochar source. The data in Figure 1 would allow an Extension educator to clearly point out that formational temperature is a highly important consideration and one should likely avoid using biochar formed at temperatures above 400°C. Moreover, the data indicate that more (higher application rates) are not always better when it comes to biochar application. In fact, the data in Figure 1 indicate that there is little if there is any statistical distinction between plant growth over the range of application rates.

Based on the data in Figure 1, an extension educator would be able to explain to this hypothetical grower that greater than 50% reduction in plant growth for high formational temperature biochars may occur, and that the additional expense of high application rates may not be justified given the variability of response shown. These are valuable science-based points of discussion for extension clients across a variety of interests and levels of implementation including urban home gardeners, small organic vegetable production operations, or large-scale production horticulture enterprises. From the data presented in Figure 1, an extension bulletin will be prepared to discuss the non-intuitive depressive effect that certain biochars and/or soil application rates may have on crop growth.

This paper clearly outlines the value of preliminary screening studies like the one described herein to determine experimental treatment parameters and generate science-based information from which to educate the public through extension programs.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Employment Prospects for Agricultural Graduates in Guinea Conakry

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Unemployment of graduates is a challenging problem in Africa, and it is aggravated by many factors such as population growth, mismatch between curriculum and employer needs, and lack of evidence-based policy making. In this context, the objectives of the present study are twofold. First, the aim is to identify key characteristics influencing labor market participation of graduates from agricultural higher education in Guinea. Second, the aim is to identify agricultural labor market needs in terms of skills and profiles desired by employers. Telephone surveys were administered to recent graduates from the main agricultural higher education institutions. The major findings from the analysis suggest that about one third of Guinean agricultural university graduates in the 2008-2013 period were employed in the formal sector in 2013-2014. Employment rates are lower for the technical schools. In terms of job creation prospects, key employers expect a doubling of hiring for positions requiring technical school or university training. Most of the projected growth is expected in the private sector. The results indicate that male graduates have a 7% higher probability of being employed as compared to female graduates in the aggregate analysis.

Key words: Youth, gender, employment, university, graduates, technical schools, labor market.

INTRODUCTION

In Africa, there are widespread media reports of high unemployment and underemployment among technical school and university graduates. Though, African governments proclaim that food security is a top priority, agricultural graduates are reported to struggle to find jobs. Quantitative studies of the employment prospects of graduates are rare, but seem to show that finding a

formal sector position in Africa often requires several years of job search, and graduate employment success varies widely from country to country. One of the reasons given for the mixed employment success is the mismatch between what employers want and the traditional higher education curriculum used by most African technical schools and universities.

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The goal of this study is to analyze the formal sector employment experience of Guinean agricultural higher education graduates, determine the key factors in finding formal sector employment, identify future prospects for employment and describe the skills profile that Guinean agricultural employers seek. The study is based on telephone surveys of recent graduates from Guinean institutions of higher education in agricultural disciplines analyzed using a Probit model and key informant interviews with agricultural employers. The article is of interest to university and technical school administrators, to government agencies that fund and regulate higher education, agricultural employers and donors. The study results have implications beyond Guinea because many African countries face similar problems. In addition to the analysis of the Guinean situation, the study demonstrates a cost effective methodology by which the higher education institutions themselves can collect key labor market data using student volunteers to contact alumni and key informant interviews with potential employers.

For the purposes of this study, the formal sector is defined to include any business and/or organization operating in the agricultural sector that is registered with the Guinean tax authorities, which may include farmers' associations and agricultural cooperatives, agricultural donors and non-governmental organizations (NGOs). The structure of formal employment in Guinea remains dominated by the public sector and formal sector enterprises. However, in 2012, only 10% of the national workforce was employed in these sectors (IMF, 2013). In urban areas, about 28% of the workforce is in formal sector jobs, while only 3.5% of the workforce is in the formal sector in rural areas. The majority of these formal sector jobs are in the capital Conakry and the regional capitals. The rest of the workforce is employed in informal occupations which are concentrated in the agricultural sector.

The agricultural sector in Guinea remains the primary source of employment. However, there are major gaps in terms of the analysis of the operating dynamics in the agricultural labor market. In general, 80% of the working population is employed in agriculture. Following the dismantling of the former state-dominated production system during the 1980s, the majority of the employment is available in small and medium scale informal sector farms. Apparently, there is a growing demand for technically trained workers in agriculture, but graduates struggle to find jobs that fit their training. Availability of statistical data on the development of the formal employment market in the agricultural sector is limited, but these data are necessary for rational planning of education and vocational training.

Literature review

Africa's wide labor markets struggle to absorb youth.

According to recent studies (Bloom, 2011; Proctor and Lucchesi, 2012), the youth population in sub-Saharan Africa will increase by 42.5 million between 2010 and 2020, and this is even more striking since the age group of under 14 already represents 42% of the population in the region. In a study done for the World Bank, Filmer and Fox (2014) identified agriculture as a sector with the potential to substantially increase employment. Using survey data from Conakry in Guinea, Glick and Sahn (1997) found that education and gender play a significant role in allocation of labor market participants among the different sectors. In their analysis, probabilities of employment in the private and public sectors are substantially greater for men as compared to women for all levels of educational attainment, except at the university level. Adebo and Sekumade (2013) identified some of the key factors leading Nigerian students to choose an agricultural degree program. Their analysis of data gathered from students at Ekiti State University shows that work experience in some aspect of agriculture was key and thus they recommend greater emphasis on agricultural internships and student field trips.

While media reports of high unemployment among technical school and university graduates are widespread, quantitative studies show that success in finding suitable employment seems to be related to the time since graduation and to vary widely from country to country. In a study of 691 graduates of the University of Ouagadougou who sought copies of their diploma from the registrar, only 31% found formal sector employment (Justine, 2012). Azoh et al. (2012) reported that in Cote d'Ivoire, 19% of university graduates with their first university degree (License) and 25% of Master's degree graduates were unemployed. Anyanwu (2000) found that over 90% of the 579 Nigerian graduates surveyed had found formal sector jobs and that most of those who had been out of university for more than seven years had jobs. Based on a survey of 500 randomly selected university graduates from the years 1980 to 1999 from Malawi, Tanzania, Uganda and Zimbabwe, Al-Samarrai and Bennell (2007) showed that, eight or more years after graduation, almost all the university graduates traced had wage employment related to their training. In the Al-Samarrai and Bennell (2007) study, unemployment was found among secondary school graduates.

Logit and probit analysis is commonly used to identify important factors influencing employment success. For example, Boutin (2010) presents an analysis of the factors affecting the transition of youth into the labor market in Cameroon. For this purpose, an econometric model 'Probit' is estimated based on data from the third Cameroonian investigation among household (ECAM3) conducted in 2007. It notes that the effect of the level of education on the probability of employment is ambiguous. For instance, the probability of employment for young adults with no education and with higher education is

negative and reaches -4 and -17%, respectively, where young adults with primary and/or secondary are the reference group. Nordman and Pasquier-Doumer (2014) contrast the effect of vocational training and general education on the professional integration capacity of youths in urban areas in West Africa. The analysis is performed by estimating a 'logit' model on the collected database as part of the study conducted between 2001 and 2003 in the capitals of seven countries in West Africa. Their findings suggest that individuals who had access to vocational training opportunities have a comparative advantage in the formal employment marketplace, and especially at higher levels of schooling.

The mismatch between formal agricultural training and the needs of African agribusiness employers can be seen in a study done for the Regional Universities Forum for Capacity Building in Africa (RUFORM) and Association for Strengthening Agricultural Research in East and Central Africa (ASERECA), which found that employers in Kenya, Tanzania, Rwanda, Ethiopia, Malawi and Mozambique report that agricultural graduates have weak skills in problem analysis and finding practical solution (Blackie et al., 2009). They also reported that graduates have poorly developed oral and written communication skills. In Uganda, a survey by Breazeale et al. (2004) showed that Ugandan agribusiness firms seek the same type of skills that their counterparts in the US, Canada and Australia do, with personal qualities, leadership and communications ranked at the three most important categories. A survey of 109 agribusiness firms in Nigeria, Kenya, Uganda, Mozambique and South Africa by Scheltema et al. (2014) showed that while companies see the need for better technical skills, they were particularly dissatisfied with the communications and interpersonal skills of graduates.

MATERIALS AND METHODS

Description of data collection

Given the lack of information on employment prospects of graduates of Guinean institutions of agricultural higher education, a telephone surveys was done of recent graduates to determine their employment status and the key factors that affect the probability of being employed. The data on graduates covered all the main agricultural higher education institutions in Guinea: the Institute for Agricultural and Veterinary Science Valéry Giscard d'Estaing (ISAV) at Faranah, the National Schools for Agriculture and Livestock Production (ENAE) at Macenta, Tolo, Koba and Kankan, and the National School for Water and Forestry Technicians (ENATEF) at Mamou. All the ENAE locations are public institutes under the tutelage of the Guinean Ministry of Employment, Technical Education and Vocational Training.

ISAV is the only public agricultural university in Guinea. It has a faculty of about 115 full-time teaching and research staff to support a 4-year academic program. The institute is composed of seven departments: Agronomy, Agroforestry, Rural Economy, Water and Forestry, Animal Science, Rural Engineering, and Extension. While enrollment varies from year to year depending on government

policies and other factors, as of 2007, the total student body was approximately 6,725, with women representing 21% (Diallo, 2007).

The main course of study within the ENAE culminates in a degree awarded after 3 years of studies. The ENAE offer two types of diplomas (or degrees): type "A" and type "B". The first type of diplomas is geared toward the graduates of the public school system at the "Brevet" level (equivalent to ninth grade in the US system) and results in graduates earning a degree in the areas of Agricultural or Livestock Technical Assistants. The second type of diplomas targets high school graduates (or baccalaureate), which aims at conferring degrees of Agricultural or Livestock Technical Controllers.

The Ecole Nationale des Agents Techniques des Eaux et Forêts (ENATEF) was created in 1991 in Mamou, Guinea with support from Swiss Aid. The main objective of the ENATEF is to train Forestry Technicians Agents in the field of rural development. ENATEF has a three year program and is targeted at public school graduates with the "Brevet" diploma. Access is reserved for graduates who pass the national entry examination.

In the case of ISAV, data was used from phone survey conducted in August 2013 by a team of instructors and students at ISAV, and with a technical supervision from Purdue University. It should be noted that the ISAV survey was conducted for an evaluation of ISAV before this study of graduate employment prospects started. Therefore, the ISAV questionnaire was missing two questions that, from experience, seem to be essential: a question on informal employment for graduates having no work in the formal sector, and a question on their level of English proficiency. A representative sample was randomly selected, composed of 10% of the 4,125 ISAV graduates identified during the past five years. A questionnaire was developed and administered to the graduates included in the sample via phone calls (Ouraich et al., 2015). Because phone surveys are a novelty in Guinea, almost 100% of called graduates responded to the interview call.

For the case of ENAE and ENATEF, the same procedure was adopted for the data collection on graduates, except that an almost complete census of the graduates was done. All graduates for whom a mobile phone number was available were contacted. Due to modest number of ENAE and ENATEF graduates interviews were done with all the identified graduates from those institutions, instead of a sample. In general, the number of graduates in the last five years is around one hundred for each ENAE campus. A questionnaire was developed and administered via cell phone (Ouraich et al., 2015). In a second step, the survey data was used to estimate probit models. This step allows identification of the main factors affecting the probability of obtaining employment. The data derived from the telephone survey provides information on a number of indicators identified as having a potential impact on the integration capacity on the labor market such as gender, the institution the student graduated from, specialization, knowledge and technical skills, level of mastery of foreign languages, etc.

For the second objective, a field investigation of historical and potential employers of ISAV, ENAE, and ENATEF graduates was conducted in all four regions of Guinea. Based on a questionnaire developed by the technical supervision team of Purdue University (Ouraich et al., 2015), the data collection was performed based on the face-to-face interviews with the representatives of the identified institutions. Interviews with employers were conducted in and around large urban areas in Guinea and include Conakry, N'zérékoré, Kankan, Kindia, Mamou and Labé. Traditional employers of ISAV, the ENAE and ENATEF graduates include: governmental departments within the Ministry of Agriculture, Ministry of Higher Education, and Ministry of Employment, Technical Education and Vocational Training; higher institutes and of technical training in agriculture, including ISAV and the ENAE; the Agricultural Research Institute of Guinea (IRAG); primary and

secondary schools (public and private); private building and civil engineering companies; the agricultural livestock operations (mainly poultry farms); cooperatives and farmers associations, and private farms. Among the potential employers of ISAV, the ENAE and ENATEF graduates, mining companies as well as NGOs and community organizations were included.

Survey results: A descriptive analysis

ISAV

The ISAV sample in the analysis represents about 10% of graduates in the lists of graduates numbering 4,125. Therefore, the sample size in the study amounted to about 411 graduates. The size of the final sample for the descriptive statistics and the probit analysis was 402 observations due to the elimination of observations with incomplete data. In the ISAV survey, male graduates represent 75% and women graduates represent 25%. This is roughly the same as the male/female ratio in the current student populations at the Guinean institutions. Formal sector employment rate is 34% for all ISAV graduates contacted, with 37% for male graduates and 25% for female graduates. While having one third of graduates employed would be a dismal outcome for industrialized country agricultural universities, it is similar to the graduate employment rates widely reported in the African media and documented in Burkina Faso.

ISAV graduates are not evenly distributed across departments. Four of seven departments represent jointly more than 80% of all graduates. The distribution of graduates from the four largest departments is: Rural Economy (28%), Agronomy (19%), Rural Engineering (19%), and Water and Forestry (15%). The remaining departments are much smaller representing only 20% of graduates with Agroforestry (9%), Animal Science (7%) and Extension (4%).

When the distribution is compared across gender, the distribution of female graduates across departments is more concentrated than that of male graduates. The share of female graduates in three out of seven departments is greater than 30% and they are as follows: Water and Forestry (39%), Rural Economy (35%), and Agroforestry (31%). In addition, two departments represent jointly 62% of total female graduates: Rural Economy (39%) and Water and Forestry (23%). In terms of employment by department, the highest rates of employment are exhibited by the departments of Rural Engineering (41%), Water and Forestry (39%), Rural Economy (38%) and Animal Science (38%). These departments represent jointly 79% of all employed graduates.

ENAE

In the ENAE sample, men represent 74% and women represent 26%. Male graduates represent the 81% in the employed ENAE graduates. In terms of employment rates, 14% of all graduates are employed irrespective of gender. When accounting for gender, employment rate reached 13 and 19% for female and male graduates, respectively. Unlike the Nordman and Pasquier-Doumer (2014) study, this study showed that vocational school graduates have a somewhat lower percentage of graduates employed than their colleagues who graduated from the agricultural university. In terms of employment by degree program, the highest rate of employment was exhibited by the Agriculture B (25%). For the rest of the programs, the proportion of employed graduates was below the 20% threshold and is 18% for Breeding B, 16% for Breeding A and 14% for Agriculture A. Self-employment varies widely among the ENAE campuses; Kankan – 11%; Koba – 22%; Macenta – 20%, and Tolo – 63%. The high share of self-employed among the

Tolo ENAE graduates is in part due to the fact that many graduates use the school's farm plots as a start-up location for their agricultural businesses.

The ENATEF data is based on a list of graduates during the past five years. The size of the final sample for the descriptive statistics and probit analysis is 78 observations. In the ENATEF data, male graduates are 74% of the sample, whereas female graduates account for 26%. Male graduates represent the majority in the employed respondents, and which is similar to the findings for ISAV and ENAE graduates. Overall, the rate of formal sector employment is 26%. In addition, 14% report informal sector employment. One hypothesis concerning the relatively higher employment percentage at ENATEF, as compared to the ENAE, is that the Swiss donor resources have increased the quality of the education at ENATEF and employers are responding to that quality by employing more of the ENATEF graduates. As one informal indicator of that quality, the interview team for this study indicated that the ENATEF student volunteers were substantially more articulate in the phone surveys than their ENAE counterparts.

Gender

Female graduates represent 19% of the overall graduate pool included in the surveys who are currently employed. For female ISAV graduates, 24% are employed. The number is 30% for ENATEF and 11% for the ENAE graduates. Among the ENAE locations, the rate of employment for female graduates in the formal sectors varies: 9% at ENAE-Tolo, 17% at ENAE-Koba and 20% at ENAE-Kankan. None of the female graduates from ENAE-Macenta are currently employed in the formal and informal sectors. The main reason for this situation appears to be that 20 of the 23 of the Macenta women in the sample are from the 2013 cohort. The data from all the schools indicates that graduates often require several years to find formal sector jobs. Consequently, it is not surprising that recently graduated Macenta women are unemployed.

The private sector is the major employer of female graduates. Nevertheless, the employment dynamic within the female pool of graduates offers substantial differences when compared with the general population. Female graduates rarely report self-employed status. Among those with jobs, the private sector employs 58% of female graduates from ISAV, 73% from the ENAE, and 100% from ENATEF. Within the ENAE, the share of employed female graduates working in the private sector is as follows: 50% at ENAE-Kankan, 80% at ENAE-Koba and 100% at ENAE-Tolo.

Employer perspectives

The majority of employers interviewed were from the for-profit-private sector (31 of the 70 interviewed employers). The public sector follows with 25 employers and finally the NGO sector with 14 employers. The employer hiring plans suggest that demand for employees with university or technical school degrees should double in the next few years with larger increases in some geographic areas. For example, the number of employees in the regions of Mamou and Forécariah is projected to increase by 389 and 288%. The regions of Conakry, Boffa, Labé and Kankan follow with projected increase of 161, 108, 104 and 103%, respectively. The rest of the regions show increases under the 100% threshold: 98% at Coyah, 73% at N'zérékoré, 68% at Dubréka, 61% at Macenta, 59% at Pita and 47 at Kindia.

In terms of the qualitative assessment of the graduates from ISAV, the ENAE and ENATEF by employers, the main conclusion that emerges from the analysis of the surveys is the lack of practical knowledge and experience. According to the analysis, 87% of

Table 1. Pooled probit model variables.

Variable	Description	Values
Employment	Dummy variable denoting the employment status of the interviewed graduates	Employment = 1, if formally employed Employment = 0, if not formally employed
School	Categorical variable denoting the training institution	School = 1, if from ISAV School = 2, if from ENAE School = 3, if from ENATEF
Gender	Dummy variable denoting the graduate's gender	Gender = 1, if male Gender = 0, if female
Satisfaction	Categorical variable denoting the level of satisfaction of the graduates with their training	Satisfaction = 1, if "Bad" or "Average" Satisfaction = 2, if "Good" Satisfaction = 3, if "Excellent"
Competence	Continuous variable created from the average personal evaluation scores in terms of communication capacity, analytical analysis, group work, etc.	Continuous variable

Source: Telephone surveys (Ouraich et al., 2015).

employers are critical of the gaps in terms of mastery of the technical packages at the farm level. In addition, a majority of employers mention also that they are unsatisfied with the graduates' skills level in terms of drafting technical and analytical reports (69%), oral and written communication (46%), and computer literacy (37%). When comparing the graduates of ISAV, ENAE and ENATEF, the employers' surveys indicate that the graduates from ISAV are in general well versed theoretically, but lack practical experience on the field; and vice-versa for the graduates from the ENAE. Additionally, the ENAE graduates are appreciated by employers for their willingness to relocate to rural areas, whereas the ISAV graduates showcase a strong bias in favor of urban centers. Overall, the employer comments about ISAV, ENAE and ENATEF graduates is similar to those reported in other studies of African agricultural employers (Breazeale et al., 2004; Blackie et al., 2009; Scheltema et al., 2014).

Factors affecting the employability of graduates: A probit analysis

From the results of the descriptive analysis, it is clear that the employability of graduates coming from academic and technical training in Guinea is affected by a number of factors. To better understand the effect of variables identified on the probability of being employed a single equation probit model was estimated to investigate the effect of identified factors influencing the probability of being employed for the graduates. The data collected through the surveys cover a number of explanatory variables that might affect the probability of being employed for graduates (e.g. gender, degree granting institution, field of study, etc). The probit model to estimate the probability of employment for graduates is expressed as follows:

$$Pr(\text{employment}_i = 1|X_i) = f(X_i\beta)$$

Where:

$$\text{employment}_i \begin{cases} = 1, \text{if the graduate has a formal employment} \\ = 0, \text{if the graduate does not have a formal employment} \end{cases}$$

with the vector X_i denoting the independent variables affecting the probability of being employed and $f(.)$ the cumulative function of the normal distribution. To this end, the analysis used the econometric estimation package "glm" and the function "mfx" to extract the marginal effects derived from the R econometric program analysis (R Core Team, 2013).

First, a pooled probit model (model 1) was estimated using data from the three telephone surveys and covering the variables in common in all three data sets. Table 1 summarizes the variables used in the model. The gender and school variables were based on institutional records, not survey responses (Ouraich et al., 2015). In a second step, a disaggregated probit model was estimated by separating the data derived from the three telephone surveys between those from ISAV and those from ENAE and ENATEF. The data derived from the ENAE and ENATEF surveys will be jointly analyzed given the relatively small number of observations associated with ENATEF survey. For the ISAV "probit" model (model 2), variables reported in Table 2 are used. The only difference is the ENAE and ENATEF variables are replaced by a categorical variable, "ISAV Department", for each department within ISAV. The reference category is "ISAV Agronomy Department", which takes the value 1.

For the ENAE and ENATEF "probit" model (model 3), a similar approach to the ISAV "probit" was adopted. In the ENAE and ENATEF model, the ISAV department variables are replaced by degree program categorical variables ("Agriculture A", "Agriculture B", "Breeding A", "Breeding B" and "Water and Forestry"). "Agriculture A" is the reference category for the ENAE and ENATEF degree program categorical variables. A variable for English language skills is added as "English". It takes the value of 1 when the respondent's self assessment is without English skills, 2 if the respondent's is at the beginner level, and 3 when the respondent indicates that they have the capacity to read and write.

RESULTS AND DISCUSSION

The results of the estimation of the pooled probit model shows that the variables "Gender Male", "School ENAE"

Table 2. Regression results for the three probit models.

	Model 1		Model 2		Model 3	
	Estimate	Significance level	Estimate	Significance level	Estimate	Significance level
Gender Male	0.239	**	0.39	**	0.13	
School ENAE	-0.554	***	NA		NA	
School ENATEF	-0.101		NA		NA	
ISAV Agroforestry	NA		-0.67	**	NA	
ISAV Water and Forests	NA		0.46	*	NA	
ISAV Rural Economy	NA		0.35	*	NA	
ISAV Animal Science	NA		0.18		NA	
ISAV Rural Engineering	NA		0.27		NA	
ISAV Extension	NA		-0.52		NA	
ENAE Agriculture B	NA		NA		0.42	*
ENAE Breeding A	NA		NA		0.2	
ENAE Breeding B	NA		NA		-0.07	
ENATEF Water and Forests	NA		NA		0.71	***
Satisfaction Good	0.12		0.14		0.24	
Satisfaction Excellent	0.188		0.35		0.35	
English Beginner	NA		NA		-0.04	
English Read and Write	NA		NA		-0.1	
Competence	0.302	***	0.71	***	-0.25	
Constant	-1.732	***	-3.43	***	-1.42	***
Observations	856		402		448	
Likelihood ratio	-446		-234		-189	
Akaike Inf. Crit. (AIC)	906		488		400	
R2 Pseudo (McFadden)	7		9		4	
Hannan-Quinn Criterion	918		506		418	
Schwarz's Bayesian Criterion	939		532		445	

Significance Level codes: '****' = 0.001, '***' = 0.01, '**' = 0.05, NA = not applicable

Source: Probit analysis results

and "Competence" significantly influence the probability of the graduates to being employed in the overall sample. The variable "Gender Male" is statistically significant and positive. The marginal effects estimates suggest that being a male graduate increases the probability of being employed by 7% in comparison with female graduates. The ENAE variable is negative and statistically significant, indicating that the agricultural technical school graduates have a lower probability of employment than those from ISAV or ENATEF. Based on the estimated marginal effects, being an ENAE graduate reduces the probability of being in formal employment by 16% in comparison with an ISAV graduate (statistically significant). The ENATEF variable is negative, but not statistically significant (Tables 2 and 3).

In the ISAV model analysis, the coefficient estimates for "Competence", "Gender Male" and "ISAV Agroforestry" variables are significant (Table 2). Table 4 summarizes the results of the estimation of the marginal effects. For the "Competence" variable, it can be

concluded that for a unit gain in terms of self-assessed competence, the probability of being employed for an ISAV graduate increase by 25%. Being a male ISAV alumnus is associated with an increased probability of being in employment of 13% in comparison with female ISAV alumni counterparts. Regarding the department variables, the Agroforestry, Water and Forests and Rural Economy variables are statistically significant. In comparison with their fellows from the Agronomy Department, the probability of being employed for ISAV alumnus from the Agroforestry Department decreases by 20%. Water and Forests graduates have a 17% higher probability of employment.

In the ENAE and ENATEF probit analysis, only the Water and Forests degree from ENATEF has a significant effect. The marginal effects estimates indicate that the ENATEF graduate has about a 21% higher probability of being employed than ENAE graduates. Among the ENAE graduates, the Agriculture B degree holders have an estimated 11% higher probability of employment.

Table 3. The marginal effects results for the pooled model.

	dF/dx	Std. Err.	Z	P> z	
Gender Male	0.069	0.032	2.191	0.028	**
School ENAE	-0.164	0.030	-5.409	0.000	***
School ENATEF	-0.030	0.054	-0.595	0.552	
Satisfaction Good	0.036	0.054	0.669	0.503	
Satisfaction Excellent	0.059	0.064	0.917	0.359	
Competence	0.092	0.031	3.001	0.003	***

Significance level codes: '***' = 0.001, '**' = 0.01, '*' = 0.05. DF/dx is for discrete change for all variables except competence. Source: Probit analysis results

Table 4. The marginal effects for the ISAV model.

	dF/dx	Std. Err.	Z	P> z	
Gender Male	0.133	0.053	2.505	0.012	**
ISAV Agroforestry	-0.200	0.076	-2.623	0.009	***
ISAV Water and Forests	0.172	0.093	1.853	0.064	*
ISAV Rural Economy	0.126	0.077	1.638	0.101	
ISAV Animal Science	0.066	0.110	0.600	0.549	
ISAV Rural Engineering	0.098	0.082	1.202	0.229	
ISAV Extension	-0.160	0.102	-1.579	0.114	
Satisfaction Good	0.048	0.099	0.490	0.624	
Satisfaction Excellent	0.130	0.114	1.141	0.254	
Competence	0.252	0.054	4.669	0.000	***

Significance Level codes: '***' = 0.001, '**' = 0.01, '*' = 0.05. dF/dx is for discrete change for all variables except for competence. Source: Estimation results.

Table 5. The marginal effects estimates for the ENAE and ENATEF model.

	dF/dx	Std. Err.	Z	P> z	
Gender Male	0.029	0.038	0.762	0.446	
ENAE Agriculture B	0.112	0.068	1.647	0.100	*
ENAE Breeding A	0.050	0.052	0.965	0.334	
EMAE Breeding B	-0.016	0.062	-0.253	0.800	
ENATEF Water and Forests	0.207	0.076	2.720	6.52E-03	***
Satisfaction Good	0.055	0.056	0.995	0.320	
Satisfaction Excellent	0.090	0.081	1.110	0.267	
Competence	-0.009	0.035	-0.262	0.794	
English Beginner	-0.024	0.037	-0.637	0.524	
English Read and Write	-0.052	0.085	-0.603	0.546	

Significance level codes: '***' = 0.001, '**' = 0.01, '*' = 0.05. dF/dx indicates a discrete change for all variables except competence. Source: Probit analysis results.

Apparently, ability to speak English is not a priority for the more technical jobs taken by ENAE and ENATEF graduates, while informal information suggests that it is important for ISAV graduates (Table 5).

CONCLUSIONS AND RECOMMENDATIONS

The study's objective is the evaluation of the dynamic of the agricultural formal labor market in Guinea. The data

collection was conducted through phone surveys of recent university and technical school graduates and through key informant interviews with employers. The findings from the phone surveys suggest that the rate of employment for graduates in the formal sector reaches 34% for ISAV, 26% for ENATEF and 13% for the ENAE. The private sector is the main provider of jobs for the graduates in the survey. About 66% of employed ISAV graduates in Faranah are employed in the private sector. This proportion reaches 65% for the graduates of ENATEF and 56% for the graduates of the ENAE. For the public sector, the share of graduates employed varies from 0% in the ENAE in Tolo to 28% in the ENAE in Kankan and Koba.

From the pooled econometric analysis of the phone survey data, it can be concluded that ISAV graduates are more likely to find formal sector employment than their peers in the ENAE. The probability estimates suggest that being an ENAE graduate is associated with a decreased probability for formal employment of about 16% in comparison with an ISAV graduate. Previous studies indicate that personal characteristics can have a significant effect on the estimation results. In this estimation, for example, the gender of graduates plays an important role. In the pooled estimate being a male graduate is associated with an increase in the formal employment probability of about 7%. The gender effect is surprisingly modest as compared to anecdotal accounts from other countries in Africa. Self-assessment of competence is also important. A one unit higher self-assessed level of competence is associated with an increase in the formal employment probability of about 9%.

In the disaggregated models, gender, specialization and self-assessed competence levels play a significant role in determining the probability of formal employment. The analysis suggests that being an ISAV male graduate is associated with an increase in the employment probability of about 13%. For the self-assessed competence level, a unit gain is associated with an increased probability of employment by 25%. Concerning departments, it is clear that being an ISAV graduate in Water and Forests is associated with an increase in the probability of employment of about 17% as compared to the graduates from the Agriculture department. However, the Agroforestry graduates exhibit a decrease in the employment probability by 20% in comparison with their fellows in the agriculture department.

For the ENAE and ENATEF graduates, only the training programs exhibits a statistically significant effect on employment probabilities in the formal sector. These results suggest that being an ENAE graduate in the Agriculture B program is associated with an increase in the employment probability of about 11% when compared with the Agriculture A graduates, probably because Agriculture B graduates have a baccalaureate degree

and have a higher skill level than Agriculture A. For the Water and Forests program whose graduates are entirely from ENATEF, it can be concluded that as compared to the Agriculture A graduates in the ENAE, the probability of formal employment increases with 20%.

For the employers' survey interviews, the objective was to assess the employer expertise needs, and evaluate the strengths and weaknesses of the graduates. In terms of the projections for future hiring in the short term (5 years), the results of the survey indicate that the number of employees is projected to double with most jobs for graduates in urban areas. In terms of employees' profiles that are most desired by the employers, the majority expressed a desire to hire university graduates and technicians, and especially in areas related to animal science, agricultural machinery and rural economics. Among the skills most sought after, a majority of employers express a special interest in graduates with strong mastery of technical agricultural production, oral and written communication, and a willingness to work in rural areas. Given the heterogeneous nature of the pool of current and potential employers, employers frequently express a need for specific technical skills and expertise in relation to their area of activity. Field trips and internships were suggested as ways to help students develop those specific technical skills.

Conflict of Interests

The authors have not declared any conflict of interests.

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