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A review and importance of big data analytics in food, agriculture, natural resources, and human sciences

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Abstract

Big Data Analytics (BDA) is revolutionizing decision-making but remains underutilized in Food, Agriculture, Natural Resources, and Human (FANH) sciences. This study assesses the perceived importance of data analytics knowledge among FANH professionals. It explores differences in perceptions based on workplace data analytics usage and work experience. A literature review highlights BDA's potential to improve efficiency, sustainability, and innovation in FANH disciplines. However, challenges such as inadequate education, limited resources, and institutional resistance hinder adoption. A survey of 88 former Nigerian agribusiness students assessed their proficiency in data analytics. Using MANOVA, findings show that active data analytics users value it more than non-users. Work experience alone does not significantly influence perceptions. The study highlights the need for interdisciplinary curriculum development and targeted training. Integrating analytics into FANH education can enhance decision-making, resource optimization, and sustainability.

Keywords: Big data analytics; Food; Agriculture; Natural resources; Human sciences

1. Introduction

The Food, Agriculture, Natural Resources, and Human Sciences (FANH) disciplines cover a wide array of fields related to food systems, agriculture, natural resource management, and human well-being. With the rapid advancement of data analytics, decision-making in these sectors is becoming more precise and effective, helping to address challenges such as environmental pressures, seasonal variability, and sustainable resource use. To maximize these benefits, FANH professionals need to integrate data analytics into their practices (Tantalaki et al., 2019). However, a considerable gap in data analytics skills persists within these fields, limiting their full potential. Incorporating data analytics into postsecondary education remains a challenge due to factors such as limited faculty expertise, resource constraints, and a lack of interdisciplinary collaboration. Strengthening partnerships between data scientists and FANH professionals is essential to developing curricula that are both technically sound and practically relevant (McKim et al., 2018). This study investigated the perceived importance of data analytics knowledge and skills and analyzed differences in perceptions based on workplace data analytics usage and work experience. The research addressed three key questions: RQ1: What knowledge and skills in data analytics are visualization, statistical methods, and advanced analytics) when analyzed by work experience or data analytics usage?

2. Application of Big Data Analytics in FANH Sciences: A Literature Review

Big Data Analytics (BDA) has become a cornerstone of innovation in various industries, transforming how decisions are made and challenges are addressed (Jamarani et al., 2024). Fields such as finance, healthcare, and engineering have capitalized on advanced data analytics to achieve real-time insights, optimize operations, and predict future trends

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(Addo-Tenkorang & Helo, 2016). However, the Food, Agriculture, Natural Resources, and Human (FANH) sciences lag in leveraging the full potential of these technologies. This disparity not only limits the ability of FANH sectors to improve efficiency and sustainability but also highlights the urgent need for adopting big data-driven solutions.

In finance, BDA is instrumental in driving real-time market analysis, fraud detection, and risk management (Hasan et al., 2020). Financial institutions employ sophisticated machine learning algorithms to detect transactional anomalies, safeguard against fraud, and optimize investments (Ravi & Kamaruddin, 2017). Real-time trading platforms use big data to analyze vast volumes of financial data, enabling informed and timely decisions that improve profitability and reduce risks (Hasan et al., 2020). Similarly, healthcare systems utilize big data for patient diagnostics, personalized medicine, and disease outbreak monitoring (Kumar & Singh, 2019). By integrating predictive analytics into electronic health records, healthcare providers can identify at-risk patients, enhance treatment accuracy, and reduce overall costs (Batko & Ślęzak, 2022).

Engineering, too, has embraced BDA, leveraging it for smart infrastructure development, predictive maintenance, and process optimization. For instance, sensors embedded in machinery provide real-time feedback, allowing for precise control and adjustments that minimize inefficiencies. These innovations underscore the transformative power of big data in reshaping traditional approaches to problem-solving across disciplines (Zafar et al., 2017).

In comparison, the FANH sciences have made limited strides in adopting similar technologies. While precision agriculture has benefited from big data through remote sensing and variable-rate technology for optimizing water and fertilizer use, broader applications, such as predictive supply chain modeling and market trend analysis, remain underdeveloped. For instance, FANH sectors have yet to widely adopt data analytics for climate impact modeling, pest and disease prediction, or consumer behavior analysis. This gap signifies untapped potential that, if addressed, could revolutionize how food systems operate.

Several challenges hinder the adoption of BDA in the FANH sciences. One prominent issue is the lack of specialized educational programs tailored to the integration of data science and FANH disciplines. Current curricula often fail to adequately prepare students to apply advanced data analytics in areas such as pest control, climate modeling, or supply chain logistics. This educational gap results in a workforce that lacks the necessary expertise to drive innovation in FANH sectors.

Resource constraints further exacerbate the issue. Many institutions, particularly those serving smallholder farmers or operating in resource-limited regions, struggle with inadequate funding for infrastructure and technology. The high costs of acquiring and maintaining big data tools deter widespread adoption. Cultural and institutional resistance also plays a role, as reliance on traditional practices and skepticism about technological advancements impede progress. This resistance often stems from a lack of understanding of BDA's potential benefits and concerns about disrupting established systems.

Moreover, data management challenges persist. The collection, storage, and processing of vast datasets from diverse sources such as satellites, sensors, and field observations present significant technical and logistical hurdles. Issues related to inconsistent data standards and interoperability further complicate the effective use of big data in FANH applications.

To address these barriers, several key steps must be taken. Interdisciplinary curriculum development is critical for equipping future professionals with the skills needed to apply data analytics in FANH contexts. Educational programs should integrate machine learning, agricultural data visualization, and supply chain modeling to prepare a workforce capable of addressing modern agricultural challenges. Artificial intelligence (AI) and internet of things (IoT) technologies should also be prioritized to enable predictive modeling, optimize resource use, and enhance resilience to climate impacts.

Investments in capacity building and infrastructure are equally vital. Low-cost, accessible tools tailored for smallholder farmers can democratize the use of data analytics. Partnerships between government agencies, private sectors, and research institutions can help bridge funding gaps and provide necessary resources. Additionally, leveraging advancements in remote sensing, such as UAV-based monitoring and GIS integration, can improve the scalability and precision of solutions, benefiting both local farms and national agricultural systems.

In summary, while the FANH sciences lag other sectors in adopting big data analytics, the potential for transformation remains immense. By addressing educational gaps, investing in infrastructure, and fostering a culture of innovation, FANH can unlock the benefits of data-driven decision-making. Drawing inspiration from industries like finance, healthcare, and engineering, FANH sectors could enhance efficiency, improve sustainability, and contribute to global food security.

3. Reason for conducting the need assessment:

The rationale for conducting a needs assessment in data analytics for the Food, Agriculture, Natural Resources, and Human (FANH) sciences stems from the critical role these disciplines play in addressing global challenges such as food security, sustainability, and climate change. Big data analytics offers transformative potential to enhance decision-making and operational efficiency in FANH fields by enabling applications like predictive modeling, resource optimization, and supply chain management (Natrajan & Sanjeev, 2023). However, despite the rapid adoption of data analytics in other sectors such as healthcare and finance, its use in FANH remains limited. This discrepancy highlights the urgent need to align educational programs with the evolving demands of the workforce.

Existing research reveals significant gaps in the skills of FANH professionals, with many graduates lacking proficiency in key areas such as statistical techniques, data visualization, and higher-order analytical skills (Kumar & Singh, 2019). These deficiencies hinder their ability to leverage modern data-driven technologies effectively. Surveys of alumni from FANH-related fields further underscore these challenges, revealing that advanced skills, including machine learning, are underdeveloped, even among those actively using data analytics in their jobs. Foundational concepts, while relatively better understood, also require enhancement to meet industry expectations (Ben-Assuli et al., 2019). Addressing these gaps is essential to prepare graduates for the increasing complexity of modern agricultural systems.

The demand for data-savvy professionals in FANH is further emphasized by workforce trends. Careers in data science are among the fastest-growing fields, with a projected 36% increase in job opportunities between 2021 and 2031(Addo-Tenkorang & Helo, 2016). Despite this growth, FANH graduates are often underprepared for roles requiring advanced data analytics capabilities. Conducting a needs assessment allows educators to identify the most critical skills and competencies valued by employers, ensuring that curriculum development aligns with real-world requirements. Differentiated training approaches can also address the varying needs of undergraduate and graduate students, tailoring content to their respective career pathways. For instance, undergraduates may benefit from a focus on fundamental skills such as data management and basic statistical analysis, while graduate programs can prioritize advanced topics like machine learning and geospatial analysis.

The need for a targeted needs assessment is also evident in the broader context of promoting diversity and equity. Women and underrepresented minorities (URMs) remain significantly underrepresented in data analytics careers, including those within FANH fields. A well-conducted needs assessment can identify barriers to participation and inform the development of inclusive educational strategies. By incorporating mentorship programs, experiential learning opportunities, and differentiated pathways into the curriculum, institutions can better support diverse learners and foster an equitable learning environment.

Moreover, a needs assessment provides valuable insights into how data analytics is currently used in professional settings and identifies the skills considered most essential by industry practitioners. This real-world relevance ensures that graduates are equipped not only with theoretical knowledge but also with practical expertise to address pressing challenges in FANH. Examples include optimizing irrigation systems through predictive modeling, improving food supply chain efficiency with big data integration, and implementing climate-smart agricultural practices using advanced analytics.

Ultimately, the rationale for a needs assessment lies in its ability to create a curriculum that is evidence-based, adaptable, and aligned with the diverse needs of learners. By addressing gaps in knowledge and fostering skill development across varying educational levels and career stages, such an assessment ensures that graduates are well-prepared to meet the demands of a rapidly evolving sector. This approach not only enhances workforce readiness but also contributes to advancing the role of data analytics in addressing critical global challenges within FANH sciences.

4. Methodology

The study participants were former Nigerian students from the Department of Agribusiness. To assess data analytics knowledge and skills, we conducted and designed a questionnaire covering eight key areas, identified through a review of existing literature (Guttmann, 2018; Jones, 2020; World Economic Forum, 2018; Zin et al., 2022). The survey also collected demographic information, including educational background, gender, age group, work experience, and workplace use of data analytics.

A list of 13,962 alumni who had graduated from one of 15 departments within the College of Agriculture was obtained from the marketing department at Federal University of Agriculture Makurdi, Nigeria. The questionnaire was distributed in person, with an incentive offered to the first 400 respondents who completed it. A total of 88 valid responses were included in the final analysis. Data analysis was conducted using Multivariate Analysis of Variance (MANOVA)

5. Findings

MANOVA results revealed a statistically significant main effect for usage status [Wilks' Lambda = .90, $F(8, 492) = 6.62$, $p < .001$], indicating that individuals using data analytics perceived its overall importance differently compared to non-users. No significant main effect was found for work experience [Wilks' Lambda = .94, $F(24, 1427.60) = 1.28$, $p = .16$], nor was the interaction effect between usage status and work experience [Wilks' Lambda = .94, $F(24, 1427.60) = 1.21$, $p = .22$]. These results suggest that hands-on exposure to data analytics fosters a deeper appreciation for its relevance, regardless of career stage. Results from univariate ANOVA analyses demonstrated that sub-skills such as basic concepts, data visualization, statistical techniques, and higher-order analytical skills showed significant differences among use and non-use groups.

6. Conclusion

This assessment study highlights the importance of integrating core knowledge and skills such as statistical techniques, basic concepts, data visualization, and high-level analytical competencies into higher education offerings focused on data sciences in FANH discipline programs. Results from the MANOVA test indicated that individuals using data analytics perceived its overall importance differently compared to non-users. Sub-skills such as basic concepts, data visualization, statistical techniques, and higher-order analytical skills showed significant differences among use and non-use groups.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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