Introduction

In November 2022 the world reached a population of 8 billion people. The population is expected to increase by nearly 2 billion persons in the next 30 years, from 8 billion to 9.7 billion in 2050 and could peak at 10.4 billion in the mid-2080s. The growth has been driven by increasing numbers of people surviving to reproductive age, the gradual increase in human lifespan, increasing urbanization, and accelerating migration. Major changes in fertility rate have accompanied this growth. It took 12 years to grow from 7 to 8 billion people, it is going to take around 15 years to reach 9 billion, which is a sign that the overall growth rate of the global population is slowing. Still, some countries have high levels of fertility. Countries with the highest fertility levels tend to be those with the lowest income per capita. As a result, global population growth has become concentrated among the world's poorest countries, most of which is in sub-Saharan Africa. More than half of population growth between now and 2050 is expected to occur in Africa, because it has the highest rate of population growth among major areas. The population of sub-Saharan Africa is projected to double by 2050 (United Nations, n.d.). Africa is currently facing a food crisis due to the (after)effects of the war in Ukraine, climate change, economic issues, and the COVID-19 pandemic. Africa is not on track to meet the food security and nutrition targets of the Sustainable Development Goal 2 on Zero Hunger for 2030, and the Malabo targets of ending hunger and all forms of malnutrition by 2025. Recent estimates show that nearly 282 million people in Africa, which is about 20% of the population, were undernourished in 2022 and 868 million people were moderately or severely food insecure. The regions in Africa with the most undernourished people are Central and Eastern Africa (29.1% and 28.5%), which is respectively 57 million and 134.6 million. This paper is taking a closer look at Kenya, a country in Eastern Africa, which has a prevalence of undernourishment (PoU) of 27.8%. The PoU indicator of the FAO is derived from official country data on food supply, food consumption, and energy needs in the population, considering age, sex, and levels of physical activity. It is designed to capture a state of chronic energy deprivation. The number of severely food-insecure people in Eastern Africa was 130.9 million in 2022 and the number of moderately or severely food-insecure people was 327.4 million. Kenya's prevalence of moderate or severe insecurity had an average of 72.3% from 2020 to 2022, while the 2014-2016 average was 50.7%, so in 6 years, the prevalence increased by more than 20% (FAO, AUC, ECA and WFP, 2023). All in all, food security in Kenya has been decreasing the past decade and an increasing population will further deteriorate food security unless more actions are taken by the Kenyan government.

Kenya has an area of 582,646 square kilometres and shares a border with Tanzania, Uganda, South Sudan, Ethiopia, Somalia, and the Indian Ocean. Kenya has diverse terrains. In the east, it is bordered by the Indian Ocean with white sand beaches, azure water, mangrove swamps, and palm trees. In the north there is a small area of desert and semi-desert, which consists of sand-dunes, volcanic terrain, and forested mountains. On the western side of Kenya is the Rift Valley, which runs between Mozambique and Jordan and holds several lakes including Lake Turkana which is the world's largest permanent desert lake. Southwest of the Rift valley lies Lake Victoria, the second largest freshwater lake in the world. Furthermore, Kenya has dense rainforest and savanna grasslands (WorkingAbroad, n.d.).

The agriculture sector is very important for Kenya. It contributes 33% of the Gross Domestic Product (GDP) and another 27% of GDP indirectly through linkages with other sectors. More than 40% of the population and more than 70% of the rural population work in the agriculture sector. Agriculture accounts for 65% of the export earning and provides livelihood for more than 80% of the Kenyan population (FAO, n.d.). However, agriculture is largely subsistence and productivity has stagnated in recent years, despite population growth. Also, only about 20% of Kenyan land is suitable for farming

and these areas have not yet achieved maximum yields. Many farmers work without updated technology or basic agricultural inputs and lack financial or extension services. Recent crises such as drought, war in Ukraine, and Covid have exacerbated the vulnerability of basic livelihoods, which has a negative impact on food security (USAID, 2023).

Kenya has a wide range of soils due to variation in geology, in relief and climate. Soil resources vary from sandy to clayey, shallow to very deep and low to high fertility. However, most soils have serious limitations such as salinity, sodicity, acidity, fertility and drainage problems. The major soils in Kenya are ferralsols, vertisols, acrisols, lixisols, luvisols, nitisols, andosols, alisols, and planosols. Andosols, young volcanic soils, are porous, have a high water-storage capacity and a low bulk density and occur in areas with steep slopes and high rainfall. They are also acidic due to high levels of aluminium and the high leaching of soluble bases. Besides, andosols are susceptible to erosion as they mostly occur on steep slopes. The soils are mainly used for tea, pyrethrum, temperate crops, and dairy farming. Nitisols occur in highlands and on volcanic slopes and are developed from volcanic rocks and have better physical and chemical properties than other tropical soils. Most nitisols are acidic because of the leaching of soluble bases. Nitisols are the best agricultural soils found in the region and are used for plantation crops and food production, such as banana, tea, and coffee. Acrisols, alisols, lixisols, luvisols are soils that occur in the coffee zones in the sub-humid areas. They have a relatively low water-storage capacity, compared with nitisols. Acrisols and alisols have a low pH in wet areas, aluminium and manganese toxicities and low levels of nutrients and nutrient reserves. The 4 soils have poor structure and need erosion control measures. Ferralsols are old, highly weathered and leached soils, and the topsoil has poor fertility, whereas the subsoil has low cation exchange capacity. Phosphorus and nitrogen are always deficient, but ferralsols have a lot of aluminium and iron. Ferralsols are used to grow annual and perennial crops and are suitable for oil palm, rubber and coffee. Planosols and vertisols occur mostly in rice growing areas and are found in semi-arid and sub-humid environments. Due to the high clay content in the subsoil, this layer is impermeable in the subsoil resulting in a slow vertical and horizontal poor drainage and poor workability of the soils (Infonet Biovision, n.d.).

As stated before, Kenya’s agricultural sector is vital for its economy. The last few years, soil health in Kenya has been declining and according to Kenya’s agriculture ministry, 63% of arable land is acidic. Wakarera says many farmers double their fertilizer application if they experience low yields during a season. But if the soil's pH is unfavourable, the existing minerals in the soil cannot be absorbed by the plants, and adding more fertilizers exacerbates the problem. "We have very high soil degradation as a result of accumulation of fertilizer metals in the soil due to overuse of specific fertilizers," she says. "And what this does is that it changes the soil pH to acidic and when the soil pH is acidic the plant is not able to absorb the available nutrients in the soil." In Kenya, many farmers favour DAP fertilizer for maize, but its continuous use can lead to high soil acidity. That is why soil testing is important to determine pH levels before deciding which kind of fertilizer to use. "The lack of soil data has led to the wrong use of chemical fertilizers in a bid to increase yield, and it is having an opposite effect from what is required," she says (AfricaNews, 2024). That is why we want to create a soil health map for Kenya to identify nutrient deficiencies of the soil and to optimize fertilizer mixes at a sub-county level to improve agricultural productivity and sustainability. The soil health map is going to be created using Digital Soil Mapping (DSM), which requires environmental layers/variables, geospatially referenced soil data and a model that characterizes the relationship between the soil data and the environment to make predictions for unsampled locations (Heung et al, 2021). For mapping using Machine Learning (ML) techniques with covariates, Brus (2019) recommends selecting the sample using FSCS or cLHS. There are several valid options for sampling designs and mapping techniques. To decide which one to use, a part of the data is used to implement multiple

methods to compare which design/technique performs the best. The soil health map is used as a tool for understanding regional soil health status. Building on this, the project will propose optimized fertilizer mixes tailored for the Kenyan sub-counties. These recommendations will be based on specific crop types prevalent in each area and the corresponding soil health data and other environmental variables. The recommendations are aimed at informing policy-level decisions, helping the government to distribute fertilizer subsidies more effectively and efficiently.

Literature

United Nations. (n.d.). *Population*. United Nations; United Nations. Retrieved August 19, 2024, from https://www.un.org/en/global-issues/population

FAO, AUC, ECA and WFP. 2023. *Africa - Regional Overview of Food Security and Nutrition 2023:Statistics and trends*. Accra. https://openknowledge.fao.org/items/0db03746-74e1-4b78-9508-70b9f661859c

(link to digital report)

https://openknowledge.fao.org/server/api/core/bitstreams/dca947e8-08ca-47df-a686-48499811a2e5/content/sofi-statistics-africa-2023/prevalence-undernourishment.html

Kenya Geography and Climate | WorkingAbroad. (n.d.). Working Abroad. Retrieved August 19, 2024, from https://www.workingabroad.com/travel/kenya-geography-and-climate/

Kenya at a glance | FAO in Kenya | Food and Agriculture Organization of the United Nations. (n.d.). Retrieved August 19, 2024, from https://www.fao.org/kenya/fao-in-kenya/kenya-at-a-glance/en/

Agriculture and Food Security | Kenya. (2023, March 31). U.S. Agency for International Development. https://www.usaid.gov/kenya/document/agriculture-and-food-security

Kenyan Soils | Infonet Biovision Home. (n.d.). Retrieved June 28, 2024, from https://www.infonet-biovision.org/soil-management/kenyan-soils

AfricaNews. (2024, July 24). *Kenyan farmers turn to sustainable methods to combat soil acidity*. Africanews. https://www.africanews.com/2024/07/24/kenyan-farmers-turn-to-sustainable-methods-to-combat-soil-acidity/

Heung, B., Saurette, D., & Bulmer, C. (2021, November 25). 3.4: Digital Soil Mapping. Geosciences LibreTexts. https://geo.libretexts.org/Bookshelves/Soil_Science/Digging_into_Canadian_Soils%3A_An_Introduction_to_Soil_Science/03%3A_Digging_Deeper/3.04%3A_Digital_Soil_Mapping

Alexandre M.J-C. Wadoux, Dick J. Brus, Gerard B.M. Heuvelink, Sampling design optimization for soil mapping with random forest, Geoderma, Volume 355, 2019, 113913, ISSN 0016-7061, https://doi.org/10.1016/j.geoderma.2019.113913.