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Optimizing agricultural policy for sustainable crop production in Onondaga county: An AHP-based land suitability analysis

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A B S T R A C T

Sustainable crop production depends on data-driven decision-making to optimize agricultural policies. The present research evaluates the possibility of growing maize and apples in Onondaga County, New York, using a land suitability analysis based on the Analytical Hierarchical Process (AHP). The expected potential of land and empirical farmed land utilization differ significantly, according to our analysis of high-resolution soil, land use, and climate information. According to the current investigation, less than 5% of the county's land is now under cultivation. In fact, sufficient portions appropriate for agriculture such as 44.97% suited for apple orchards and 28.66% for maize. The main obstacles to agriculture are zoning laws that restrict agricultural growth, and land use restrictions and significant forest cover. The current research stipulates modifying zoning laws and providing financial subsidies to farmers. Further, investing in infrastructure development to increase agricultural production to maximize use of agricultural land and to promote awareness for sustainable agriculture practices. The outcomes of the study highlight evidence-based strategies which help in minimizing the gap between agriculture potential and land utilization. It also promotes steady growth of agriculture by offering particular land usage administrators, agriculture scientists, and administrators with beneficial guidelines.

1. Introduction

Profitable agriculture is vital for ensuring financial health, food security and conservation of the environment. Several biophysical parameters, such as soil properties, climate, and land use regulations, determine whether a land is appropriate for crop cultivation (Smith et al., 2019; Ennaji et al., 2018). Land compatibility evaluation or LSA has become more popular in recent years to determine the suitable locations for agricultural growth (Huang et al., 2020; Sabljić et al., 2024). Onondaga County, New York is characterized by a diverse landscape with urbanized agrarian and forest areas. Even though there is ideal soil and climate, incompatible land utilization, regulatory restrictions, dense forests and conflicting land utilization prevent agricultural land usage to achieve the maximum potential (Johnson and Brown 2018). Agricultural growth in the municipality continues to be restricted, even though there is an optimal potential for the production of apple orchards and maize (Lee et al., 2021). Moreover, sustainable agriculture productivity increased by identifying undeveloped and appropriate land areas (Deng et al., 2022). Therefore, an Analytical Hierarchical Process (AHP) has been extensively used in the agricultural compatibility field to evaluate a wide range of parameters which influence crop cultivation (Saaty 2008). By assigning percentages to variables soil PH levels, content of organic material, temperature, and rainfall, the AHP technique gives lawmakers an effective tool for decision making (Kalogiou 2019). The study aims to overcome the gap between the land's suitability and Onondaga County's current land usage by utilizing high-resolution data (Martinez-Fernandez et al., 2021).

1.2 Literature Review

The integration of interdisciplinary scientific methods such as Analytical Hierarchy Process (AHP) and geographic information system (GIS) are essential for optimize land usage and addressing the critical issue of sustainable agricultural production (Romeijn et al., 2016; Almayyahi et al., 2018). In New York, Onondaga County, application of the AHP-based suitability analysis may assist decision makers to maximize productivity, ecological conservation, and financial viability. Recently, AHP-GIS method, multi-criteria decision analysis (MCDA), multiple climatic problems and advancements in

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technology in land suitability (Salifu et al., 2022) evaluations have been extensively applied instants Singh and Swain (2019) reported that 87% of the highly and moderately suitable land produced better yields when they used AHP-GIS to evaluate the land suitability of potato crops. Future climate variables were added into land suitability models by Karapetsas et al. (2023) to point out the necessity of climate-smart agriculture. Bozdag et al. (2016) applied AHP-GIS in Cihabbeyli, Turkey, to maximize agricultural yields and propose decreasing irrigation due to soil limitations. Han et al. (2021) using an AHP-MEA model which shows a strong correlation exists between the land suitability index and the detecting crop yield in Jilin, China. Additionally, a study carried out by Bilas et al. (2022) on sustainable farming methods using LSA, focusing on conservation harvesting and residual administration. In bibliometric analysis conducted by Wijesinghe (2024), the MDCA and AHP method are progressively used to assess agricultural suitability. Applying AHP-GIS to analyze crop rotation, Singha et al. (2020) reported the optimum land allocation throughout the rice-jute and potato-lentil crop. Similarly, Saifu et al. (2022) noted that poor land use led to significant loss of Ghana's ground and maize land suitability (Martínez-Fernández et al., 2021). Furthermore, Karna et al. (2021) claim that 29% of Nepal's land is suitable for agriculture, highlighting the importance of conservation efforts. Radocai & Jurisic (2022) suggested machine learning techniques to improve GIS-based land suitability assessment (Hoffman et al., 2020). In 2023 Choudhary et al. used remote sensing technique in cloud base Google earth engine for mapping large scale farmland for agricultural policies. Further, Khaki et al. (2024) improved assessments of land production and mapped crop suitability using high resolution satellite imagery Sentinel-1 and 2. The impact of GIS-based planning influence on policy making was highlighted by Sabliic et al. (2024) in their examination of Bosnia and Herzegovina's agricultural land usage. Similarly, Mandal et al. (2020) recommended sustainable cropping sequences and different soil restoration methods in Bihar, India.

Ali et al. (2021) utilized a web-based fuzzy-AHP ELECTRE decision support system for organic rice cultivation. a fuzzy AHP-GIS model employed by Tashayo et al. (2020) to analyze land viability of wheat production in Southern Iran, focusing on soil texture, PH, slope, and electrical conductivity as significant factors. Similarly, Ennaii and colleagues (2018) using this technique to determine soil quality and salt were the most important factors deciding economic prosperity in Morocco. Neqese and Fekadu (2020) analyzed the suitability analysis for Ethiopian wheat and barley, focusing on the significance of PH, accessibility of phosphorus and total nitrogen in soil suitability. Sarı and Sari (2021) enhanced crop selection for land using the GIS based AHP and TOPSIS multiple variables assessment method. In their comparison of complicated and deterministic AHP techniques for evaluating land suitability, Romijn et al. (2016) showed that fuzzy AHP is superior to classical AHP in climate-adaptive agricultural planning. Saifu et al. (2022) created a land suitability score that shows the sustainable yield losses that might result from less-than-ideal land allocation for the cultivation of maize and groundnuts in Northern Ghana. Sarkar et al. (2021) confirmed the validity of multi-criteria decision models by creating appropriate land mapping for rice crops in India using Fuzzy AHP techniques. After evaluating the land compatibility in Nepal using AHP-GIS, Kama et al. (2021) concluded that over 39% of the area was extremely appropriate for farming. For improved agrarian land use strategy in Onondaga county, subsequent investigations should concentrate on continuous information assimilation and Al-driven support techniques. The implementation of land compatibility of algorithms for farming strategy has been investigated in several researches. For crop-specific analysis and land categorization, GIS-based AHP algorithms have already been widely utilized for different variables such as soil fertility, its PH levels, and temperature variability (Malczewski 2006; Yang et al., 2017; Handle, 2018; Zhang et al.2020). Further, policies governing land usage have a big influence on agricultural growth, especially in the case of zoning laws, conservation rules, and land ownership patterns (Nelson et al., 2019). Farming growth in Onondaga county is constrained by forest cover regulations and conflicting land uses such as urbanization and wetlands (Jones et al.2022). Research has shown change in the policy by updating zoning regulations can promote the utilization of agricultural land in underused regions (Schmidt et al., 2021).

2. Study Area

Situated in the center of New York, Onondaga County has an area of 2,090 square kilometers.

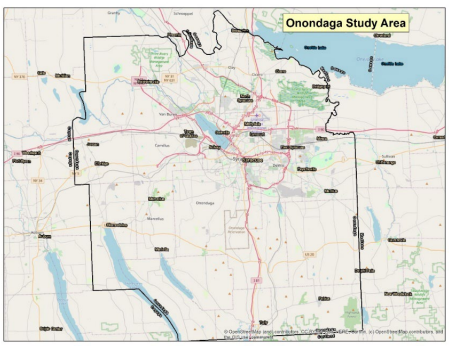

Fig. 1. Study Area Map of Onondaga County, New York
The map highlights the administrative boundary of Onondaga County, including major land features, urban areas, and agricultural zones.

According to the Onondaga County Planning Department (2023), its varied terrain includes woods, lakes, rivers, metropolitan centers, like Syracuse, and land used for agriculture. The mean monthly temperature of this County has been noted to be about 6.2 °C to 9.2 °C with annual precipitation that ranges between 980 to 1118mm, with moderate climate (NASA GISS 2023). Although the County's economy depends heavily on agriculture, the land's present usage does not match its potential for agriculture as just 5.07% of the land is appropriate for maize, whereas, less than 5% is suitable for apple orchard areas according to the US agriculture Census (2022). High levels of forest cover and restrictive zoning regulations have been noted as the two main obstacles to agricultural growth (New York Department of Agriculture, 2023). The present research work uses GIS-based AHP analysis to perform a land suitability evaluation in order to solve these issues.

2.1 Research Objective

The current research used the GIS based AHP model for evaluating the land suitability of apple and maize production in the research area (Kalogirou, S2019). The objective of the research is enlisted below:

1. To evaluate the land area is appropriate for the apple and maize crops production by applying AHP base multi-criteria assessment (MCE) and integration with data related to climatic variables, land use type, and soil characteristics.
2. To quantify the difference between actual and potential agricultural land usage by comparing the existing agriculture census to theoretical land suitability data.
3. To determine the impact of land-use policies on agricultural growth, their law of zoning, and the effect of forest cover and land use on agricultural production.
4. In order to utilize agricultural land to its full potential, drafting a new recommendation for policy making should be employed, such as infrastructure expenditures, adoption of zoning laws, and farmer incentives.
5. To promote Onondaga County's agricultural land utilization, strategic initiatives, policies should be changed for improving sustainable agricultural production and economic development.

3. Material and Methods

The current research uses a comprehensive AHP based approach to evaluate the suitability of land for sustainable growth of apple and maize in the County. Crucial factors including soil characteristics, land utilization statistics, and climate-related (Temperature and precipitation) information are incorporated into the methodology to obtain the agriculture land future potential.

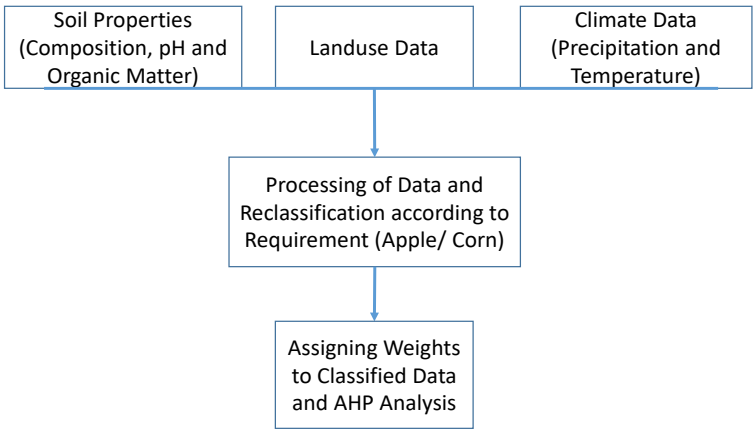

Fig. 2. Schematic Workflow of the AHP-Based Land Suitability Methodology

A visual representation of the step-by-step methodology, showing data collection, standardization, AHP analysis, and suitability mapping for maize and apple cultivation.

3.1 Soil Data Assimilation

An important factor in determining agricultural appropriateness is soil characteristics. It is essential for various crops to grow best in particular pH ranges, thus soil pH is one of these factors that significantly affects agricultural yields. The PH range in Onondaga County soil is 5.0 to 7.8, which is the ideal range for growing maize (6.0-6.8) and apples (5.5-6.5). Furthermore, it was discovered that the levels of organic matter were typically suitable for crop development, however, greater values were noted close to lakes because of the presence of more organic matter accumulation.

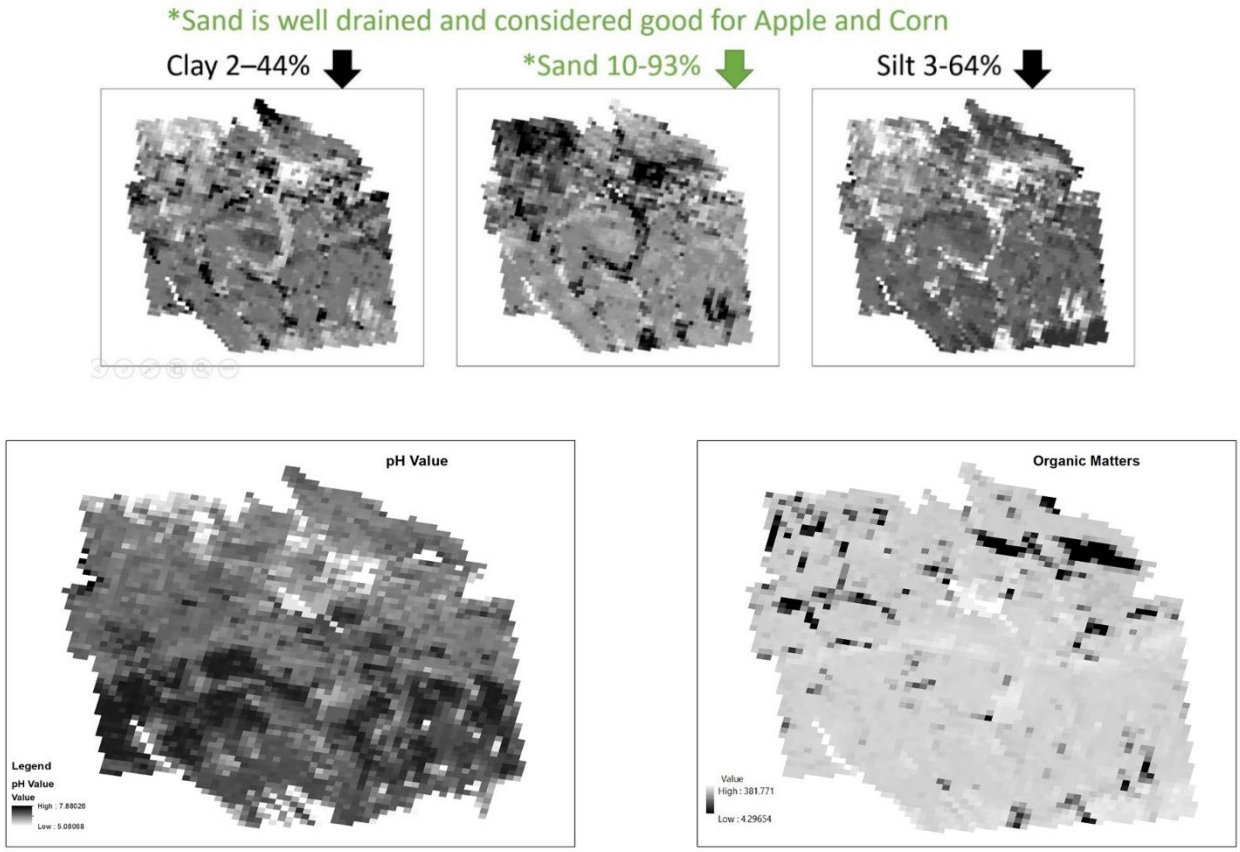

Fig. 3. Soil Data Assimilation for Onondaga County

Spatial representation of soil pH levels and organic matter distribution across the county, indicating areas suitable for maize and apple growth based on ideal soil conditions.

3.2 Data Assimilation for Land Use

A key static in the feasibility of land evaluation is land utilization categorization, which establishes the geographic distribution of urbanized agricultural, and forest regions. For evaluation, the current research used finer resolution ESRI Land Use data (10m Generalized) and high resolution MRLC Landcover 2019 data.

Data Sources for Land Use:

- **MRLC Landcover 2019:** https://www.mrlc.gov/data#
- **ESRI Landcover:** https://livingatlas.arcgis.com/landcover/

Since the AHP model is heavily impacted by land use categorization, high-resolution MRLC data was utilized to guarantee correctness, and ESRI data was reconfigured to lower the number of classification classes.

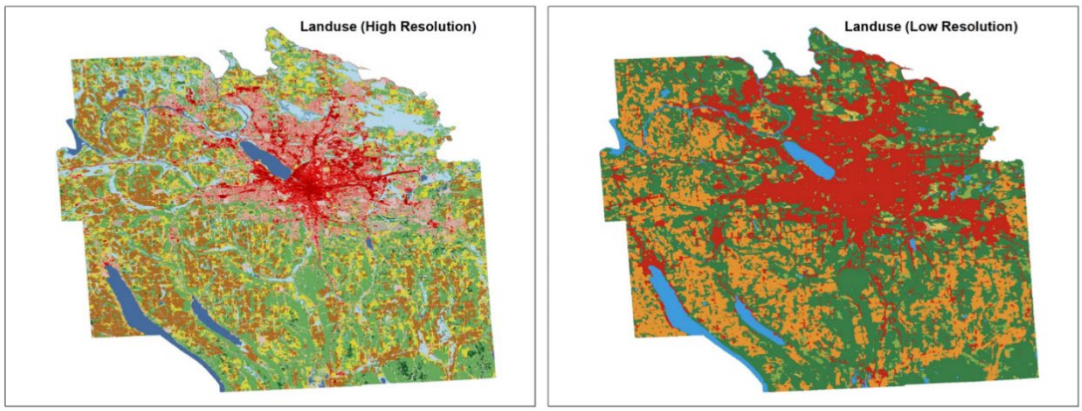

Fig. 4. Land Use Classification using High- and Low-Resolution Datasets

Comparison between ESRI 10m Generalized Land Use and MRLC 2019 high-resolution Land cover data, demonstrating land use categories influencing agricultural suitability.

3.3 Climatic Variable Data (Temperature and Precipitation)

Climatic variables that directly impact crop output and growth cycles include temperature and precipitation. To verify trustworthiness, the study used ten years of temperature and precipitation data from NASA's GPM datasets, which was then cross-checked with World Climate data.

Data source for climatic variables:

- **NASA GPM Data:** https://gpm.nasa.gov/data
- **NASA GISS Climate Data:** https://data.giss.nasa.gov/
- **WorldClim Climate Data:** https://www.worldclim.org/data/index.html

Onondaga County has an average monthly temperature range between 6.2 to 9.2°C with annual precipitation ranges between 980 to 1118mm. Despite variations in rainfall patterns, these climatic parameters are within the range considered suitable for growing maize and apples.

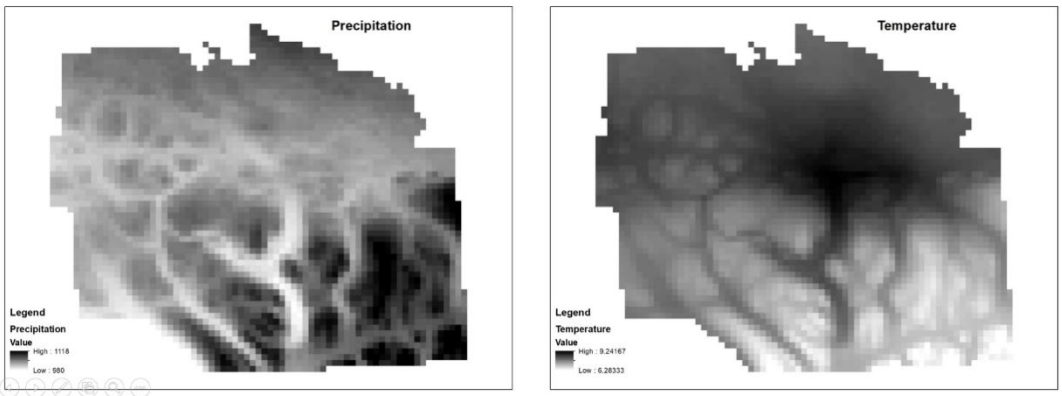

Fig. 5. Climatic Variables: Precipitation and Temperature Distribution

Spatial patterns of annual precipitation (left) and average monthly temperature (right) across Onondaga County, derived from NASA GPM and World Climatic datasets.

3.4. Reclassification and data processing

An essential element of the present investigation was data processing and reclassification. As part of the technique, all datasets were clipped to meet the boundaries of Onondaga County.

1. Establishing a standard and structuring statistics following the specifications of the AHP model (Han et al., 2021).
2. Redefining datasets according to their appropriateness for corn and apple production into five to ten classes.
3. Visualization of data and categorization refining using QGIS software
4. The New York government GIS portal provided the official Onondaga County border information gathered from the following source (http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=927).

3.5 Weight Assignment and AHP Evaluation

Weights were given to each datum according to how significant they were in assessing the appropriateness of the land for growing apples and maize. The following factors were given weights by the AHP models:

- The composition of the soil (pH, amount of organic matter, drainage capacity)
- Category of Land Use (urban, agriculture, and forest regions).
- Climate variables, such as precipitation and temperature.

AHP's pairwise comparison approach was used, and a weighted scale ranging from 1 to 9 was employed. The ArcGIS-AHP tool was used to perform the final AHP step, guaranteeing a methodical assessment of several criteria to get suitability ratings for every land unit.

4. Results and Discussion

4.1 Analysis of crop suitability

According to the results of the AHP-based land suitability assessment, Onondaga County has a subsequent amount of agricultural potential for the production of maize and apples, whereas, due to conflicting land requirements and land regulations of land use as there is a significant disparity between the theoretical and actual land utilization.

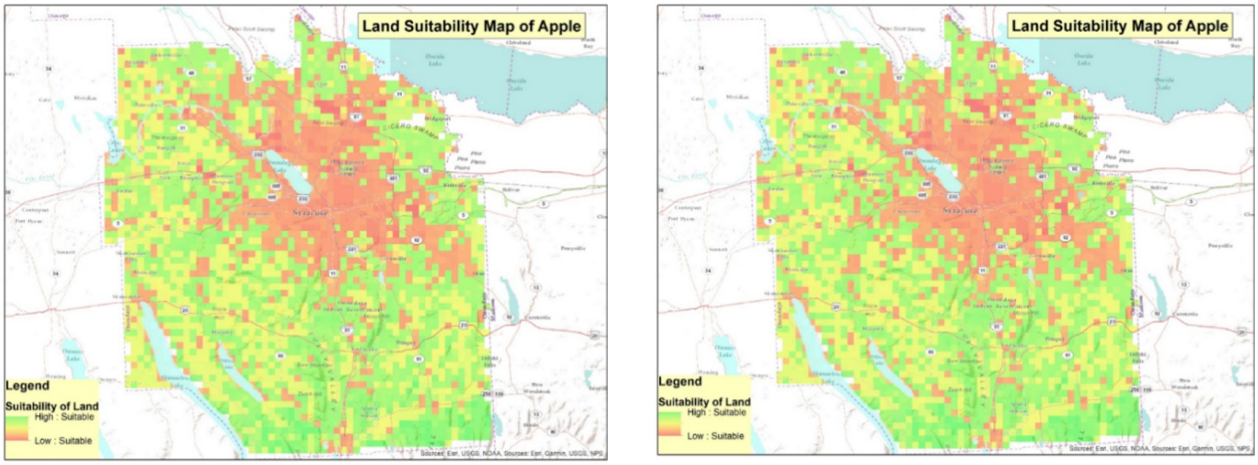

Fig. 6. Crop Suitability Analysis Results for Apple and Maize

HP-based suitability maps displaying areas classified as highly suitable, moderately suitable, and unsuitable for apple (left) and maize (right) cultivation.

LAND SUITABILITY CLASSES	AREA SUITABLE (Hectare) FOR APPLE	AREA SUITABLE (Hectare) FOR CORN
Extreme Suitable	24309.74692	21917.56362
Strong Suitable	51140.98356	25408.85694
Suitable	14223.78809	9827.34416
Moderate	17456.46721	29999.26112
Moderate	32973.32695	30581.14334
Not Suitable	5883.475984	29611.33964
Strong Not Suitable	33102.63411	33684.51518
Extreme Not Suitable	20301.22483	18361.61672

LAND SUITABILITY CLASSES	AREA SUITABLE (%) FOR APPLE	AREA SUITABLE (%) FOR CORN
Extreme Suitable	12.19%	10.99%
Strong Suitable	25.65%	12.74%
Suitable	7.13%	4.93%
TOTAL	**44.97%**	**28.66%**

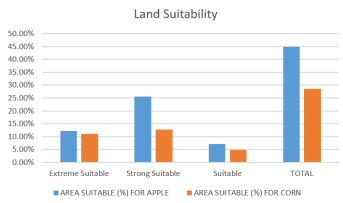

Fig. 7. Land Suitability Classification Map

Final aggregated land suitability map combining soil, climate, and land use factors, categorized into high, medium, and low suitability zones for agricultural use.

4.1.1 Apple Cultivation Compatibility

With almost 600 producers and more than 11 million apple trees, New York State is one of the top apple-producing states in the union, making a substantial contribution to the local economy and food supply (USDA, 2022). Apple orchards need around 20 inches (508mm) of water during the growing season and do best on loamy soil, well-drained soil with pH ranges between 5.5 and 6.5 (Handley, 2018). Furthermore, to guarantee appropriate blooming and fruit development, the majority of apple types require 500-1000 chill hours, or a temperature under 7°C (Zhang et al., 2020). Onondaga County satisfies the requirements for apple growing, according to the AHP analysis:

- **Soil pH:** 5.0 to 7.8 (ideal stretch for apples: 5.5–6.5)
- **Yearly Precipitation:** 980–1118 mm
- **Monthly Average Temperature:** 6.2–9.2°C

According to the results of the research, 44.97% of the County's land area is ideal for apple orchards, whereas, due to limited forest cover, land use zoning and market demand, fewer than 5% of this acreage is being employed for apple production.

4.1.2 Corn Cultivation Compatibility

In accordance with the number of seeds planted and maturity date, corn, a major crop in the United States, needs 22-30 inches (558-762mm) of water each year and thrives on rich, well-drained soils with a pH range of 6.0-6.8 (Krueger et al., 2021). Although maize can withstand short temperature oscillations (from 0ºC to 45ºC), 20-22ºC is considered the ideal growth season temperature (Ficklin et al., 2018).

Onondaga County satisfies a portion of the requirements for corn growing, according to the AHP analysis:

- **Soil pH:** 5.0 to 7.8 (ideal stretch for corn: 6.0–6.8)
- **Yearly Precipitation:** 980–1118 mm
- **Monthly Average Temperature:** 6.2–9.2°C

According to the outcomes of the present research, 28.66% of the County's land area is ideal for corn production, whereas, land use constraints and alternative planning options contribute to the current underutilization of this land, which is just 5.07% utilized for maize farming.

4.2 Analysis of AHP Land Suitability

The findings show that maize compatibility is more regionally limited due to environmental and land use restrictions, apple production is highly suited over the majority of Onondaga County.

Key Outcomes:

Apple constraints: Most of Onondaga County satisfies the standards for temperature, precipitation, and soil pH for apple orchards.

Corn constraints: while corn agriculture is somewhat appropriate in the western and northwest regions, it is less appropriate in the southern regions because of the heavy rainfall and deep forest cover.

4.3 Land use Disparity

Although less than 5% of the land is now used for apple orchards, 44.97% of it is suitable for such operations. Further, 5.07% of the land is currently utilized for corn production, 22.66% of the land is suitable for corn agriculture. The main constraints are from Zoning regulations, market forces, and limitations on forest cover.

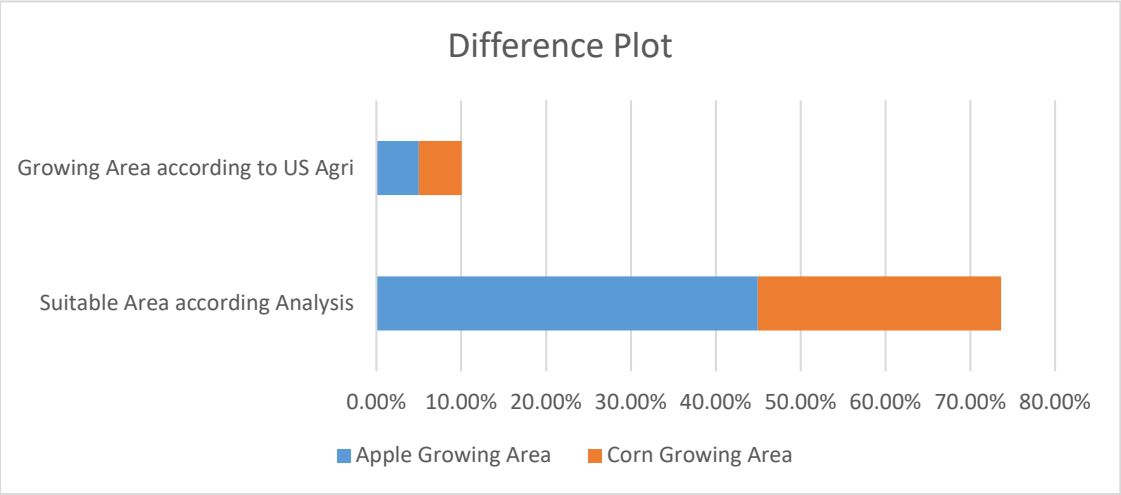

Fig. 8. Comparison of Theoretical Suitability and Actual Cultivated Area

Bar plot or map (if visual) showing disparity between total land area deemed suitable for apple and maize cultivation and the area currently under cultivation.

5. Conclusion

The current investigation has focused on how much of Onondaga County's ideal agricultural land is underutilized, especially for maize and apple orchards. Although present land use rules and zoning constraints prohibit full agriculture usage, the AHP-based research indicates that a significant amount of land satisfies ideal soil and climate conditions for these crops. Policy makers need to consider the following suggestion maximize land use and improve agricultural productivity:

1. Modifying land use laws to give more appropriate land to maize and apple orchards.
2. Encouraging sustainable agricultural growth in low-density forest regions where soil and climatic conditions are conducive.
3. Offering farmers financial incentives to maximize the maize and orchard yield, especially in underdeveloped areas.
4. Making investments in land management and irrigation techniques to lessen the effects of rainfall on corn production.
5. By employing remote sensing and GIS-Based techniques, consistent monitoring and changes that occur in order to assist adaptive agriculture policies.

Thus, Onondaga County may boost its agricultural productivity, increase economic sustainability, and guarantee effective land use while upholding environmental conservation initiatives by putting these suggestions into practice.

References

Ali, M., Khan, S., & Hussain, A. (2021). A web-based decision support system integrating fuzzy-AHP and ELECTRE for organic rice cultivation. *Information Processing in Agriculture, 8*(1), 123–134.

Almayyahi, H. M., & Al-Attab, R. J. (2024). Land suitability analysis for wheat cultivation in Iraq using GIS and AHP techniques. *Journal of the Saudi Society of Agricultural Sciences, 23*(1), 45–54.

Bilas, G., Singh, S., & Singh, R. (2022). Land suitability analysis for sustainable cropping systems in the Indo-Gangetic Plains of India. *Agricultural Systems, 195*, 103279.

Bozdağ, A., Yavuz, F., & Günay, A. S. (2016). AHP-GIS based site suitability determination for vineyard plantation: A case study of Turgutlu district. *Computers and Electronics in Agriculture, 113*, 62–73.

Choudhary, S., Sharma, L. K., & Singh, V. (2023). Remote sensing and Google Earth Engine for agricultural policy planning: A case study of crop mapping in India. *Environmental Monitoring and Assessment, 195*(2), 256.

Deng, X., Li, Y., Zhang, H., & Wang, J. (2022). GIS and AHP in Sustainable Agriculture. *Computers and Electronics in Agriculture*, 195, 106797.

Ennaji, W., El Harti, A., & Bannari, A. (2018). GIS-AHP based land suitability assessment for agricultural crops: Case study of Tadla Plain, Morocco. *Geocarto International, 33*(5), 443–457.

Fekadu, G., & Negese, T. (2020). Land suitability analysis for wheat and barley crops using a GIS-based multi-criteria approach: In the case of Duna Woreda, Ethiopia. *Cogent Food & Agriculture, 6*(1), 1766737.

Ficklin, D. L., Abatzoglou, J. T., Robeson, S. M., & Knouft, J. H. (2018). Climate and Corn Suitability. *Agricultural Water Management*, 202, 1-12.

Han, H., Yang, C., & Song, J. (2021). Land suitability assessment for maize using AHP and MEA models in Jilin Province, China. *Sustainability, 13*(15), 8572.

Handley, J. (2018). Irrigation Requirements for Apple Orchards. *Montana Ag Research Bulletin*.

Hoffman, G., Miller, T., Zhang, L., & Chen, Y. (2020). GIS-Based Corn Suitability Models. *Precision Agriculture*, 21(3), 571-587.

Huang, C., Li, Y., Zhang, W., & Chen, J. (2020). Advancing Land Suitability Analysis for Crop Planning. *Agricultural Systems*, 182, 102851.

Johnson, M., & Brown, K. (2018). Zoning and Agricultural Land Use: Implications for Sustainability. *Land Use Policy*, 77, 364-375.

Kalogirou, S. (2019). Multi-Criteria Land Suitability Analysis. *International Journal of Geographical Information Science*, 33(2), 273-290.

Karapetsas, N., Kalfas, C. A., & Galatsidas, S. (2023). Climate-smart agriculture: Adoption, impacts, and implications for sustainability. *Mitigation and Adaptation Strategies for Global Change, 28*(5), 1–23.

Karna, B., Devkota, B., & Paudel, B. (2021). Land suitability evaluation for major crops using AHP and GIS: A case study of Kaski District, Nepal. *Journal of Agriculture and Natural Resources, 4*(1), 1–14.

Khaki, M., Awange, J., & Forootan, E. (2024). Integrating Sentinel-1 and Sentinel-2 imagery for crop suitability mapping to improve land productivity assessments. *International Journal of Applied Earth Observation and Geoinformation, 112*, 102953.

Krueger, B., Thompson, L., Ahmed, S., & Wang, Y. (2021). Corn Water Requirements and Soil Suitability. *Agronomy Journal*, 113(4), 1561-1578.

Lee, D., Kim, S., Alvarez, J., & Thompson, R. (2021). Land Use Challenges in Agricultural Planning. *Environmental Research Letters*, 16(5), 054012.

Malczewski, J. (2006). GIS-Based Multi-Criteria Decision Analysis. *Progress in Planning*, 67(1), 3-65.

Mandal, U. K., Singh, R., & Sharma, S. K. (2020). Sustainable cropping sequences for soil health and productivity in Bihar, India. *Agricultural Research, 9*(3), 402–412.

Martínez-Fernández, J., López, M., García, R., & Torres, A. (2021). Land Suitability for Orchards. *Remote Sensing of Environment*, 252, 112107.

NASA GISS. (2023). *Onondaga Climate Data Analysis*.

Nelson, T., Ramirez, L., Gupta, N., & Zhao, H. (2019). Agricultural Zoning and Policy. *Land Use Science Journal*, 14(2), 212-227.

Onondaga County Planning Department. (2023). *Annual Land Use Report*.

Radočaj, D., & Jurišić, D. (2022). Improving GIS-based land suitability analysis using machine learning models: A case study of agricultural land in Croatia. *Computers and Electronics in Agriculture, 193*, 106650.

Romeijn, P., Bierkens, M. F. P., & Stoorvogel, J. J. (2016). A comparison of deterministic and complex analytical hierarchy process methods for land suitability assessment. *Soil Use and Management, 32*(4), 584–594.

Saaty, T. (2008). The Analytical Hierarchical Process. *Operations Research*, *12*(1), 83-98.

Sabljić, M., Marković, D., & Lukić, T. (2024). GIS-based agricultural land use planning in Bosnia and Herzegovina: Implications for policy-making. *Land Use Policy, 108*, 105536.

Salifu, A., Abdulai, A.-L., & Donkoh, S. A. (2022). Land suitability assessment for maize and groundnut production in Northern Ghana using GIS and AHP. *Spatial Information Research, 30*(1), 123–137.

Sarı, R., & Sari, D. (2021). Integration of AHP and TOPSIS for optimizing crop selection in land consolidation areas. *Land Use Policy, 101*, 105142.

Schmidt, L., Johnson, M., Patel, S., & Rivera, T. (2021). Policy Interventions for Sustainable Agriculture. *Journal of Policy Analysis*, 58(4), 734-748.

Singha, C., & Swain, K. C. (2019). Land suitability assessment for potato crop using analytic hierarchy process technique and geographic information system. *Journal of Agricultural Engineering, 56*(3), 78–87.

Singha, C., Swain, K. C., & Swain, S. K. (2020). Best crop rotation selection with GIS-AHP technique using soil nutrient variability. *Agriculture, 10*(6), 213.

Smith, J., Brown, A., Lee, K., & Patel, R. (2019). Sustainable Agriculture: A GIS-Based Approach. *Journal of Environmental Planning*, 45(3), 321-335.

Tashayo, B., Gholami, V., & Karami, G. (2020). Application of a fuzzy AHP-GIS model for land suitability assessment in wheat farming: A case study of Southern Iran. *Soil and Tillage Research, 196*, 104442.

USDA. (2022). Apple Production in the United States. *US Department of Agriculture Report*.

Wijesinghe, D. C. (2024). A bibliometric review of geospatial analyses and artificial intelligence in agricultural land suitability assessments. *GeoJournal, 89*(2), 567–589.

Yang, W., Liu, H., Zhang, Y., & Chen, X. (2017).. Soil Suitability and Crop Yield Optimization. *Geoderma*, 289, 39-49.

Zhang, L., Smith, J., Chen, Y., & Davis, M. (2020). Chill Hour Requirements for Apple Cultivation. *Horticultural Science*, 55(6), 842-851.