



**Analysis of Potatoes Growing Decisions with the Analytic Hierarchy
Process Method in Burundi**

Thierry Keringingo*, Zuhul Karakayacı¹

¹ Department of Agricultural Economics, Faculty of Agriculture, Selcuk University, Türkiye

*Department of Agricultural Economics, Faculty of Agriculture, Selcuk University, Türkiye

thiekera@gmail.com.



Abstract

Analysis of Potatoes Growing Decisions with the Analytic Hierarchy Process Method in Burundi

Potatoes cropping are paramount in Burundi and almost all the provinces of the country grow potatoes. However, there are several varieties of potatoes grown in Burundi. Farmers are facing with the difficulties of deciding which right variety of potatoes to grow. This work was carried out for helping farmers to make the right choice of the variety to grow. Analytic Hierarchy Process (AHP) method has been used. The Ndinamagara, Ingabire and Victoria potatoes varieties were the different decisions alternatives. The Prices of seeds, Yield, Marketing, Cost of producing and Sustainability were the main criteria that were taken as the accountment for taking the decision process. In this work, it was a question of developing a multi-criteria decision-making process and determining the appropriate potatoes production system with the AHP method. The results shown that each criterion had its own highly preferred variety. According to the seed price criterion, the Victoria variety was found to be more important than the others. The Victoria potatoes had a priority weight of 66.4%. Since the coherence ratio was less than 0.10, the matrix was seen as coherent. For the yield criterion, the Ndinamagara variety has a weight of 50.1% and the consistency ratio was less than 0.10. According to the marketing criteria, the Ndinamagara variety still had a weight of 60.7% of points and the consistency ratio was also less than 0.10 and the matrix was also consistent. For the production cost criterion, the Victoria variety has a weight of 70.2%. For the sustainability criterion, the Ndinamagara variety has been found to be more important and had a weight of 0.776 points and the consistency ratio was 0.10. In concluding, for the final decision, the Victoria variety was determined to have a greater weight (48.6%) than the Ndinamagara variety (31.8%) and the Ingabire variety represented as the last with a rate of 19.6%. Considering the results of this work, the suitable potatoes variety was decided as Victoria variety.

Article Info

Author(s): Zuhail Karakayaci

Thierry Keringingo

Received : 03/04/2022

Accepted in revised form : 20/04/2022

Published : 30/04/2022

Corresponding author :

thiekera@gmail.com.

Keywords :

Multi-Criteria Decision Making, Analytic Hierarchical Process, Potatoes, Growing Decisions, Burundi



1. Introduction

Potatoes are tubers produced by the species *Solanum tuberosum*, belonging to the Solanaceae family. It is native to the Andes Mountains in South America and more precisely to Peru. The Incas cultivated it under the name of "Papa" about 1000 years before J.C. Introduced in Europe in the sixteenth century, its food qualities were initially unknown, and it was not clear how to name it: *truffe* in France, *Kartoffel* in German, *potato* in English, *patata* in Spanish and Italian. The name potato has been said to have used for the first time in 1762 by the botanist Henri Louis Duhamel du Monceau (Harahagazwe et al, 2012). Its vegetative cycle is about 80 to 90 days. Compared to other tubers; its shortly maturity allows it to be grown all year round in rainy and irrigated systems (Okonkwo, 1992). Potatoes are grown in more than 150 countries and play an efficient role in the world food system. It is the main non-grain food product in the world; it ranks fourth after wheat, rice and corn, which form the basics of human nutrition (FAOSTAT, 2015). Worldwidely, 376,875,686 tons of potatoes are produced per year. China is the largest potato producer in the whole world with 99,122,420 tons of production volume per year. India comes as the second producer with 43,770,000 tons of annual production (ATLAS, 2022). Table 1 illustrates the top 10 potato-producing countries in the world during the 2021 year.

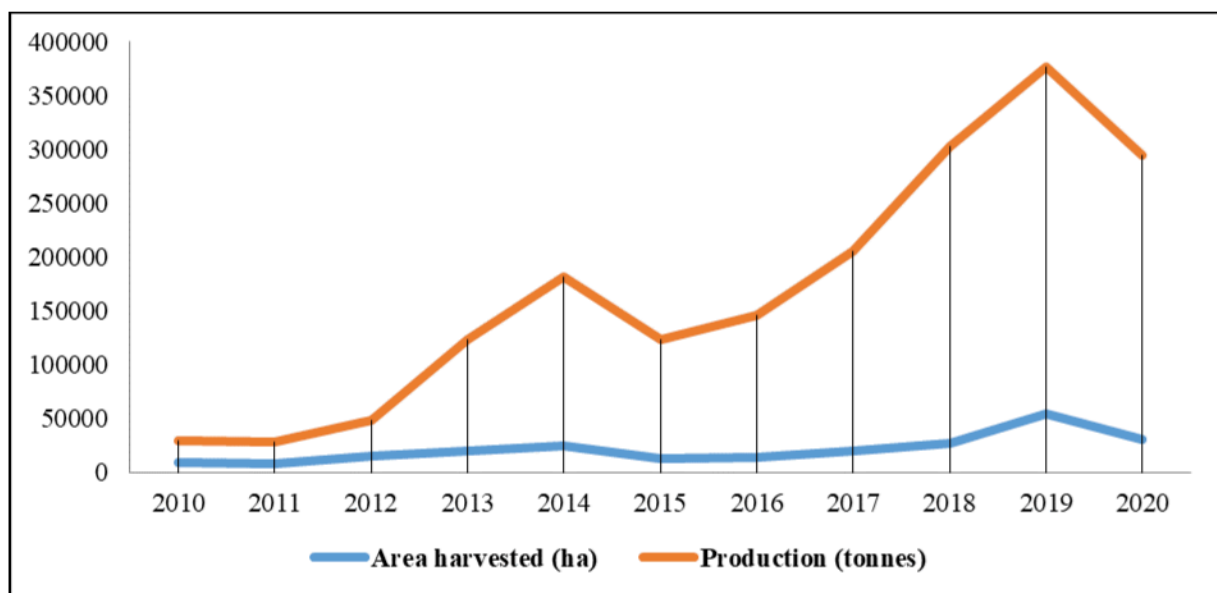
Table 1. Top 10 potatoes producing countries in the world

Countries	Production (tons)	Production / person (Kg)	Planting area (ha)
China	99.122.420	71,11	5.815.140
India	43.770.000	32,75	2.130.000
Russian	31.107.797	211,79	2.030.858
Ukraine	21.750.290	514,63	1.311.600
United States of America	19.990.950	60,99	407.810
Germany	10.772.100	130,19	242.500
Bangladesh	9.474.099	57,37	475.699
Poland	8.872.445	230,85	311.620
France	6.834.680	101,56	175.225
Netherlands	6.534.338	378,77	155.594
Belarus	5.985.810	631,53	292.401

Source: (ATLAS, 2022)



Potatoes production had increased significantly in sub-Saharan Africa, reflecting the importance of the crop in the region. This increase was due to a rapid expansion of the planting area from 100,000 ha in 1994 to 240,000 ha in 2004 in the Great Lakes Region (Burundi, Rwanda, DR Congo and south-western Uganda) (Bararyenya et al, 2012). In Burundi and especially in its production area (Mugamba region), potatoes are taken as the first crop in terms of income (22%), the first root and tuber crop most appreciated and consumed in urban areas and the 4th in terms of food security (16.7%) (Harahagazwe et al, 2012).



Source: (FAOSTAT, 2022)

Figure1. Evolution of potatoes production in Burundi (2010- 2020)

Currently, 8 varieties are in wide distribution namely: Ndinamagara (the most used with 51%), Victoria (the 2nd with 16%). Ingabire, Ruhanyura, Magome, Rukuzi, Uganda 11 and Mabondo have not yet achieved successfully in broadcast despite their various quality. In Burundi, 94.3% of the population depends on food agriculture, and rural development begins mainly with agriculture and livestock (MINAEGRIE, 2011). Potatoes are a cash flow in various regions, where it suits better.

The objectives of this study are to determine the level of priority given by farmer's from the basic business decisions of producers and the criteria that are effective in making these decisions using Analytic Hierarchy Process (AHP). The study aimed to develop a multi-criteria decision-making process and implement a decision support system for the agricultural sector. Certain criteria were used to determine whether Ndinamagara potatoes, Victoria potatoes and Ingabire potatoes one of them should be preferred as the first potato in production. These criteria are chosen according to the prices, yields, marketing, cost and sus-



2. Material and Method

Mugamba natural region was the main object of our study because it is a region where potatoes are a staple crop. To carry out this work, secondary data were used. These data were for 2019-2020's production period. Secondary data were on different potato varieties. And among these varieties, Ingabire varieties, Ndinamagara varieties and Victoria varieties have been chosen to serve as our decision choices.

Life is guided by the decisions made, whether it's personal or professional. In man's life, world and history have always been full of lessons that help him to realize these critical moments. Those life lessons are learned in trying and using examples. Making a decision quickly can be detrimental, but also delaying on decision can also cause the loss of opportunities. The main thing is systematic and comprehensive approach to decision-making. Decision-making is based on improving the quality of life and achieving the goal of life (Saaty, 2001). There are six basic steps to follow in decision-making process: (a) determination of the problem in question and the factors that have impacted, (b) determination of decision criteria and objectives, (c) formulate a model or a relation between the objectives and the decisions' variables, (d) identification and evaluation of alternative solutions, (e) choosing the best alternative and lastly (f) implementation of the decision (Heizer and Render, 2003). For this work, a literature review was carried out to realize a situation of potatoes crop.

In addition, publications and statistics of public institutions and organizations are related to the topics that were consulted. In this study, the AHP method, which is one of the methods of multicriteria in decisions-making and one of the modern methods of decision support, was examined. A purpose of choosing a method of the Analytical Hierarchical Process (AHP) as a subject of this study is to help the decisions-makers to solve many complex decisions problem. In AHP, hierarchy is created by determination of the main criteria and its own alternatives. In terms of the accuracy and reliability of establishing a model, it should be noted as the hierarchical structure best reflects for this model (Aslan, 2009). The AHP is based on individual comparisons of the factors affecting the decision importance values of the decision itself points of these factors on the decision hierarchy using a predefined comparison scale. The Standard Preference Table is a scale table consulting of odd numbers, where the even numbers between them are also used as intermediate values.



Table 2. Comparison Scale of Pairwise Saaty

Intensity of importance	Explanation
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very high importance
9	Extreme importance
2, 4, 6 and 8	Intermediate values

After determining the relative importance of the elements in the comparison matrices of the AHP method, the order comes to calculate the Consistency Ratio (CR) of judgments in each comparison matrix to measure whether of the decision-maker behaves consistently when comparing the elements of the hierarchy. The goal of implementation of this stage is to study the quality, accuracy, validity and reliability of the final decision has to be made (Saaty, 2000). The consistency index (CI) of the entire decision-making process and its hierarchy can also be calculated in AHP. This ratio also makes it possible to measure the consistency of the entire decision-making process. This measure, called the Consistency Ratio (CR) makes it possible to identify poor evaluations of decision-makers in comparisons. A consistency ratio of 0.10 (which is acceptable upper limit for the CR) roughly expresses that there is a 10% probability that the elements were compared completely randomly. If the CR is higher than 0.10, the decision-maker is advised to reconsider his comparison. This is due to the fact that some of the decision-maker's assessments are contradictory (Topel, 2006).

$$\text{Consistency index} = \frac{\lambda_{\max} - n}{n - 1}$$

$$\lambda_{\max} = \frac{\sum_{i=1}^n di}{n}$$

And

$$\text{Consistency Ratio} = \frac{\text{Consistency index}}{\text{Random index}}$$

As a result of the study conducted on more than a hundred samples at the Oak Ridge National Laboratory, the random index for matrices of dimensions 1 to 15 is given in Table 3 (Topel, 2006).



Table 3. The RI values according to the dimensions of the comparison matrices

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.59

After determining the values of CI and RI, the Consistency Ratio (Consistence Ratio-CR) was calculated using:

$$CR = \frac{CI}{RI}$$

With this equality, it is decided that the comparison matrix is consistent if the defined CR is less than 0.10.

3. Results

As can be seen in the hierarchical tree model in Figure 1, the goal is to create an appropriate production system taking into account the following criteria: price, yield, marketing, cost and sustainability. The following potatoes varieties Ndinamagara, Victoria and Ingabire are the different alternatives of choice.

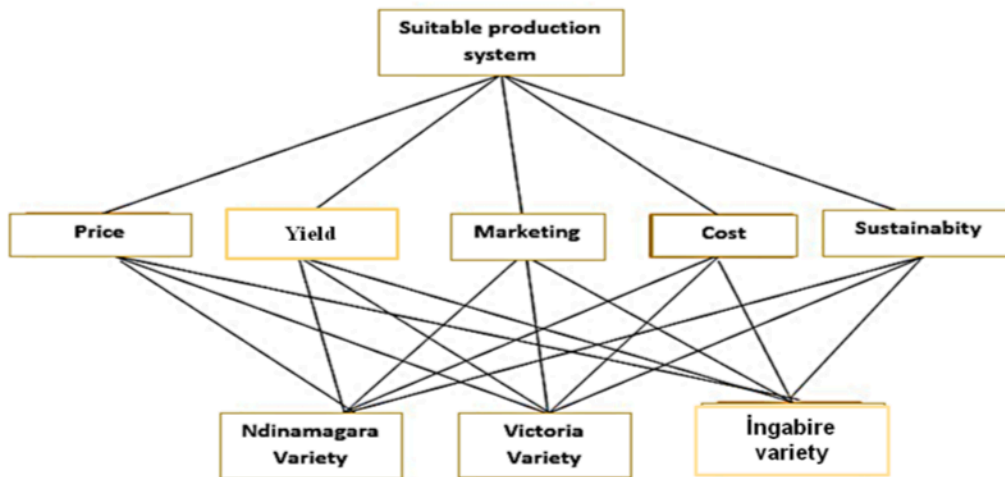


Figure 2. Hierarchical tree model

Table 4 illustrates matrix of comparing the criteria for choosing between them. The quotes are given by experts in the field or sometimes are drawn from surveys that had been made.



Table 4. Criteria comparison matrix

	Price	Yield	Marketing	Cost	Sustainability
Price	1	3	5	3	3
Yield	1/3	1	3	1/3	7
Marketing	1/5	1/3	1	1/5	1/3
Cost	1/3	3	5	1	5
Sustainability	1/3	1/7	3	1/5	1

Up to now, a matrix hasn't been reached by comparing the potatoes alternatives to be selected based on these criteria. Using the same method, it is also necessary to decipher the order of importance of the criteria among themselves. As in Table 5, the first matrix is constructed using the values of a normalized table.

Table 5. Comparisons of normalized factors

	Price	Yield	Marketing	Cost	Sustainability	Total	W (Weight)
Price	0,45	0,4012	0,2941	0,6338	0,1836	1,97	0,3935
Yield	0,15	0,1337	0,1764	0,0703	0,4285	0,96	0,1922
Marketing	0,09	0,0445	0,0588	0,0422	0,0203	0,26	0,0513
Cost	0,15	0,4012	0,2941	0,2112	0,3061	1,36	0,2728
Sustainability	0,15	0,0191	0,1764	0,0422	0,0612	0,45	0,0901

$$\lambda_{\max} = ((1,97/0,3935)+(0,96/0,1922)+(0,26/0,0513)+(1,36/0,2728)+(0,45/0,0901))/5 = 5,0081 = 5,01$$

$$CI = (\lambda_{\max} - n)/(n-1) = CI = (5,01-5)/(5-1) = 0,01/4 = 0,002$$

$$RI = \text{Random index} = 1,12 \text{ and Consistency Ratio (CR)} = CI/RI = 0,002/1,12 = 0,002.$$

The most important value that should be paid attention to is the consistency ratio. The consistency ratio should be less than 0.10. The CR of the criteria turned out to be 0.002 in the comparison matrix. Since this ratio is less than 0.10, it was decided that the criteria comparison matrix is consistent. Analyzing the weight of the criteria, the price criterion is clearly the first in this choice of potatoes, and then the cost and yield follow as summarized in Table 6.

**Table 6. Values of the weights of the criteria**

Criteria	W (Weight)
Price	0,3935
Yield	0,1921
Marketing	0,0513
Cost	0,2728
Sustainability	0,0901

Table 6 shows the comparison of alternatives according to the price criterion and their priority points as well as their weights.

Table 6. Normalized price comparison matrix

	Ndinamagara variety	Victoria variety	Ingabire variety	Total	W
Ndinamagara variety	0,2381	0,2172	0,25	0,7052	0,2351
Victoria variety	0,7142	0,6523	0,625	1,9916	0,6638
Kirundo variety	0,0476	0,1304	0,125	0,3031	0,1011

In order to determine the consistency of the triple comparison matrix of alternatives according to the price criterion, the relative weight of the matrix (λ_{max}) must first be calculated.

$$\lambda_{max} = ((0,7052/ 0,2351)+(1,9916/ 0,6638)+(0,3031/ 0,1011))/3 = 3,00008.$$

$$CI = (\lambda_{max} - n)/(n-1) = CI = (3-3)/(3-1) = 0$$

$$RI = \text{Random index} = 0,58$$

$$\text{Consistency ratio (CR)} = CI/RI = 0/ 0,58 = 0.$$

Since the consistency ratio (CR) is less than 0.1, the triple comparison matrix of alternatives according to the price criterion consistent. For the price criterion, Victoria potatoes were considered more important than others. Victoria variety has a priority weight of 66.4%. Since the consistency ratio is less than 0.10, the matrix turned out to be consistent. After the price criteria, the triple comparison matrix on the yield criterion is given in the triple comparison matrix table 7.

**Table 7. Normalized yield comparison matrix**

	Ndinamagara variety	Victoria variety	Ingabire variety	Total	W
Ndinamagara variety	0,5455	0,3333	0,625	1,5038	0,5012
Victoria variety	0,1816	0,1111	0,0625	0,3552	0,1184
Kirundo variety	0,2727	0,5555	0,3125	1,1408	0,3802

$$\lambda_{\max} = ((1,5038/0,5012)+(0,3552/0,1184)+(1,1408/0,3802))/3 = 3.$$

$$CI = (\lambda_{\max} - n)/(n-1) = CI = (3-3)/(3-1) = 0/2=0$$

$$RI=0,58 \text{ and the } CR = CI/RI = 0/0,58 = 0.$$

In table 7, the comparison of alternatives according to the yield criterion and their priority weights are presented. For the yield criterion, Ndinamagara potatoes had a weight of 50.1%, the consistency ratio was less than 0.10 and then matrix turned out to be consistent. Table 8 clarifies the triple comparison matrix based on marketing criteria.

Table 8. Normalized marketing comparison matrix

	Ndinamagara variety	Victoria variety	Ingabire variety	Total	W
Ndinamagara variety	0,6523	0,4545	0,7142	1,8211	0,6071
Victoria variety	0,1304	0,0911	0,0476	0,2689	0,0896
Kirundo variety	0,2172	0,4545	0,2381	0,9098	0,3032

$$\lambda_{\max} = ((1,8211/0,6071)+(0,2689/0,0896)+(0,9098/0,3032))/3 = 2,99 = 3.$$

$$CI = (\lambda_{\max} - n)/(n-1) = CI = (3-3)/(3-1) = 0/2=0$$

$$RI=0,58 \text{ and } CR = CI/RI = 0/0,58 = 0.$$

Regarding marketing, Ndinamagara variety has a weight of 60.7%. The consistency ratio was less than 0.10, the matrix turned out to be consistent. Table 9 and 10 respectively shows that the triple comparison of potatoes varieties based on their cost and sustainability criteria.

**Table 9. Normalized cost comparison matrix**

	Ndinamagara variety	Victoria variety	Ingabire variety	Total	W
Ndinamagara variety	0,1111	0,1463	0,0454	0,3028	0,1009
Victoria variety	0,5555	0,7315	0,8182	2,1053	0,7017
Ingabire variety	0,3333	0,1221	0,1363	0,5918	0,1972

$$\lambda_{\max} = ((0,3028/0,1009)+(2,1053/0,7017)+(0,5918/0,1972))/3 = 2,9999=3$$

$$CI = (\lambda_{\max} - n)/(n-1) = CI = (3-3)/(3-1) = 0/2=0$$

$$RI = 0,58, CR = CI/RI = 0/0,58 = 0.$$

For the cost criterion, Victoria variety potatoes had a weight of 70.2% points. The consistency ratio was observed and matrix was found to be consistent.

Table 10. Normalized sustainability comparison matrix

	Ndinamagara	Victoria	Ingabire	Total	W
Ndinamagara variety	0,7974	0,6923	0,8401	2,3297	0,7765
Victoria variety	0,0881	0,0769	0,0399	0,2054	0,0684
Ingabire variety	0,1142	0,2307	0,1200	0,4648	0,1549

$$\lambda_{\max} = ((2,3297/0,7765)+(0,2054/0,0684)+(0,4648/0,1549))/3 = 3,00001=3$$

$$CI = (\lambda_{\max} - n)/(n-1) = CI = (3-3)/(3-1) = 0/2=0; RI = 0,58 \text{ and the CR was } 0.$$



According to the sustainability criterion, Ndinamagara potatoes had been turned out as the more important and had a weight of 77.6%. Consistency ratio was 0.10.

In determining the appropriate production system using the AHP method was established. First a comparison of the criteria was carried out, then a comparison of the alternatives according to each criterion. According to the criteria and the relative importance values of the alternatives were obtained by combining the relative importance values of the alternatives and the relative importance values of the criteria. The relative importance values of the alternatives are multiplied by the corresponding weight in the relative importance values of the criteria and the sum of the row in which they are located was taken. Thus, the weight of the alternatives breaks down among themselves. The relative importance values of the alternatives are given in Table 11.

Table 11. Multiplication of matrices

Alternatives	Price	Yield	Marketing	Cost	Sustainability
Ndinamagara variety	0,2351	0,5012	0,6071	0,1009	0,7765
Victoria variety	0,6638	0,1184	0,0896	0,7017	0,0684
Ingabire variety	0,1011	0,3802	0,3032	0,1972	0,1549

X

Criteria	W (Weight)
Price	0,3935
Yield	0,1921
Marketing	0,0513
Cost	0,2728
Sustainability	0,0901

The last calculation that has been performed will be to add up the row where each alternative is located in the matrix of alternatives by multiplying their values.

$$\text{Ndinamagaravariety : } (0,2351*0,3935)+(0,5012*0,1921)+(0,6071*0,0513)+ (0,1009*0,2728) + (0,7765*0,0901) = \mathbf{0,3175}$$

$$\text{Victoria variety : } (0,6638 *0,3935)+(0, 1184*0,1921)+(0, 0896*0,0513)+ (0, 7017*0,2728)+ (0, 0684*0,0901) =\mathbf{0,4862}$$

$$\text{Kirundo variety : } (0, 1011*0,3935)+(0, 3802*0,1921)+(0, 3032*0,0513)+(0, 197289*0,272849) + (0, 154936*0,090103) = \mathbf{0,1962}$$



Table 12 gives the final result on the potato type, which was decided using the AHP method.

Table 12. Selected potatoes

Alternatifves	Points	
Ndinamagara variety	0,3175	31,75%
Victoria variety	0,4862	48,63%
Kirundo variety	0,1961	19,62%
Total	1	100,00%

In the final decision, Victoria variety potatoes were the first decided with a rate of 48.6%, in second place comes Ndinamagara variety (0.318) and Ingabire potato (0.196) was determined to have a lower weight than other varieties. Given in this example, the Victoria potatoes were decided as a suitable variety for the potatoes growing system in Burundi. This research with the AHP method for variety decision is the first study done in this Mugamba region.

4. Conclusion

The AHP method of multi-criteria decision-making was provided as being important in this study. It clarifies the potato variety that can meet the different criteria and finally become the appropriate production system in Burundi. In this work, it was shown that the appropriate production system for potatoes growers is Victoria variety. The other potatoes varieties proved to be more important either in terms of price, yield, marketing and sustainability criteria. For properly conducting a good agricultural practice that can satisfy all the criteria in making crop choices, it is recommended to resort to the AHP method. Therefore, producers should be oriented towards the production of Victoria variety, and incentives and supports should be provided to producers to strengthen their decision-making process. In order to transfer resources to the future generations in a most efficient way, efforts should be focused informing producers about the conscious use of inputs.



5. References

- Aslan, E., 2009. Bulanık Analitik Hiyerarşi Prosesi Yöntemi Yardımıyla Tedarikçi Seçimi ve Üretim Sektöründe Bir Uygulama. Dokuz Eylül Üniversitesi Sosyal Bilimleri Enstitüsü.
- ATLAS, 2022. La Production Mondiale de pomme de terre. <https://www.atlasbig.com/fr-lu/pays-par-production-de-pommes-de-terre> 31.03.2022.
- Bararyenya A, Inamahoro M, Niko N, Ntahimpera A and Nayihanzamaso P, 2012. <https://isabu.bi/wp-content/uploads/2021/09/Livret-Acquits-de-la-composante-pomme-de-terre.pdf> 05/3/2022
- FAOSTAT, 2022: Statistiques de la FAO. <https://agronomie.info/fr/economie-de-la-pomme-de-terre/>
- FAOSTAT,2015: Statistiques de la FAO. <https://agronomie.info/fr/economie-de-la-pomme-de-terre/>
- Harahagazwe, D., Ledent, J. F., & Rusuku, G. (2012). Growth analysis and modelling of CIP potato genotypes for their characterization in two contrasting environments of Burundi. African Journal of Agricultural Research, 7(46), 6173-6185. <https://ifdc.org/wp-content/uploads/2020/11/Article-basse-altitude-PDT-1.pdf>
- Heizer, J. ve Render, B., 2003. Operations Management, 8th Edition. Pearson Education Inc. New Jersey.
- MINEAGRIE, 2011: Evaluation des récoltes, des approvisionnements alimentaires de la situation nutritionnelle saison a 2011
- Okonkwo, J.C., 1992: Irish potato production in Nigeria. Training Workshop Paper, NRCRI, Vom, Nigeria.
- Saat, M., 2000. Çok Amaçlı Karar Vermede Bir Yaklaşım: Analitik Hiyerarşi Yöntemi. Gazi Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi 2: 149-162.
- Saaty, T. L., 1990. Multicriteria Decision Making: The Analytic Hierarchy Process, RWS Publications, 2nd Edition, Pittsburgh, s.54.
- Saaty, T. L., 2001. Decision Making With Dependence and Feedback: Analytic Network Process, RWS Publications.
- Topel, A., 2006. Analitik Hiyerarşi Prosesinin Bulanık Mantık Ortamındaki Uygulamaları-Bulanık Analitik Hiyerarşi Prosesi. (Yüksek Lisans Tezi), İstanbul Üniversitesi Sosyal Bilimleri Enstitüsü, İstanbul