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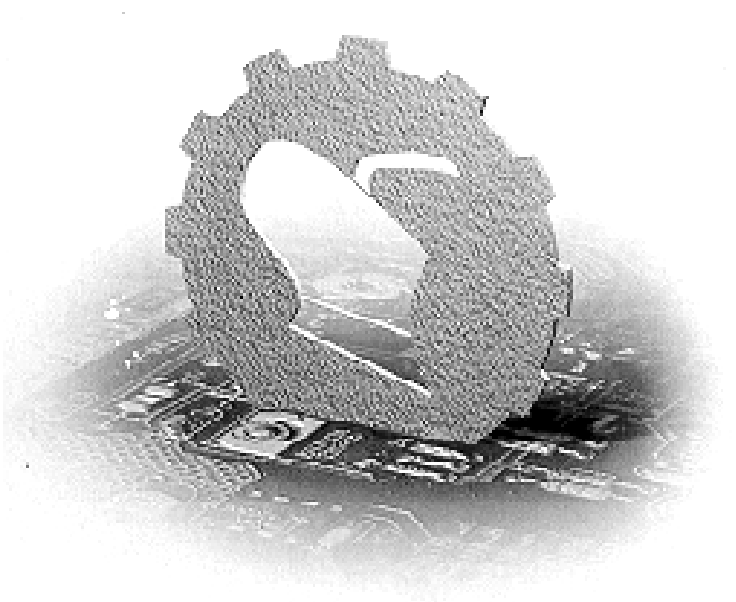

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PROCUREMENT OF AGRICULTURAL MECHANISM THROUGH IPARD MEASURE-1, AND APPLICATION OF MARKETING IN THE MEANING OF EXPLANATING THE PROFITABILITY OF INVESTMENTS BY THE ADVISORY SERVICE

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Abstract. The study showed the importance of marketing in terms of making a business decision on the purchase of agricultural machinery that is not older than five years for the needs of the agricultural economy.
In this study, the authors determined that there is a strong influence between the three influencing factors on the conditions of purchasing agricultural machinery (the existence of the possibility of refunds in the amount of 60-70%), and in relation to cases where marketing was used by the advisory service for agriculture, that is, when there was no direct marketing activity regarding the possibility of using IPARD-1 for the purpose of purchasing agricultural machinery.
In addition, we found that T-values differ significantly in cases of not using marketing and its value ranges from 15,253 to 25,455, but in the case of applying marketing in relation to the purchase of new agricultural machinery, that interval would be even higher, that is, the significance is even higher, larger and ranges from 17,331 to 31,456.

Key words*: IPARD-1, agricultural machinery, marketing, refund.*

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INTRODUCTION

Making valid management decisions of individual agricultural producers is of great importance for the optimal and rational spending of funds that are used in accordance with the same decisions [1-5], especially regarding the purchase of large items in the organization of agriculture, such as the purchase of agricultural machinery and mechanization.

Such activities are accompanied by other segments of influence on decision-making, such as the application of advertising, propaganda, emphasizing the advantages of financing through the use of various funds in agriculture [6-11].

In addition, upgrading in agriculture can also mean making business decisions in accordance with rational decisions regarding the purchase of agricultural machinery, where very often the agricultural advisory service can play a positive role in the case of the purchase of necessary inputs related to the organization of agricultural production [12-16].

MATERIALS AND METHODS

For the purposes of this study, the authors surveyed 55 individual producers who did not apply marketing when purchasing agricultural machinery and 89 of those who applied marketing, meaning a total of 144 such participants in the Republic of Serbia were surveyed. The research period was 01.09. to 30.09. 2024.

The factors of the return of funds through the IPARD-1 measure to encourage the purchase of agricultural machinery were analyzed, as follows: the first case, which implied a 60% return of money from the total eligible investment costs, 65% of the investment if it is a mountainous area, as well as 70% in the case when the investment was made by a young farmer.

After that, the authors performed statistical data processing using the IBM SPSS (Statistical Package of Social Science) software version 25, which was strengthened by applying the t test.

The level of 0.05 was used as the threshold value of significance.

RESEARCH RESULTS AND DISCUSSIONS

The aim of the research was to reveal possible differences in relation to the procurement of agricultural machinery using the IPARDA-1 measures and the behavior of individual farms in this regard.

The observation was carried out in conditions when there was no application of marketing, that is, in another case when there was application of marketing in relation to the procurement of agricultural machinery.

In this way, it would be possible to clarify the importance of the procurement in relation to the existence of the marketing advisory agricultural service, which would provide additional explanations about the possibility of refunding funds. All of this was strengthened based on statistical processing using a t-test to reveal the significance of relationships on this issue.

Below is a presentation of Tables 1-2, which depict the results obtained in relation to the cases of non-application of marketing and application of marketing in order to promote the IPARD-1 measure based on the procurement of agricultural machinery.

Table 1. Assessment of the evaluation of the procurement of tractors through IPARD-1, without the use of marketing in relation to agricultural holdings in the R. of Serbia

IPARD-1 incentive factors		Mean	Standard deviation	T-value	p
60% of the total eligible investment costs	Without marketing (N=55)	2.66	0.69	15.254	<0.0005*
65% of the investment if it is a mountainous area	Without marketing (N=55)	4.43	0.70	15.622	<0.0005*
70% in the case when the investment was made by a young farmer	Without marketing (N=55)	4.65	0.71	25.455	<0.0005*

Table 2. Assessment of the evaluation of the purchase of tractors through IPARD-1, with the application of marketing advisory services in relation to agricultural holdings in the R. of Serbia

IPARD-1 incentive factors		Mean	Standard deviation	T-value	p
60% of the total eligible investment costs	With the application of marketing (N=89)	2.81	0.69	17.331	<0.0005*
65% of the investment if it is a mountainous area	With the application of marketing (N=89)	3.42	0.68	19.245	<0.0005*
70% in the case when the investment was made by a young farmer	With the application of marketing (N=89)	5.15	0.66	31.456	<0.0005*

Based on the presented results (Table 1), it can be seen that there is a significant difference in terms of the analyzed influencing factors on the return of funds through the application of IPARD-1 funds. That difference increases as percentages of refunds related to cases where no marketing is applied by the agricultural extension service increase.

Similar behavior is also visible after displaying Table 2, that is, it can be seen that there is a significant difference in terms of the analyzed factors influencing the return of funds through the application of IPARD-1 funds.

At the same time, the difference increases as the percentages of refunds of the analyzed factors, which refer to the cases when marketing is applied by the advisory agricultural service, increase. However, in the case of marketing applications, higher values of the T-test are seen, which indicates a strong dependence of the return of money through the mentioned fund in relation to the form of the analyzed return factor.

CONCLUSION

The obtained results of the study indicate that there is a great importance of applying marketing in relation to making an important business decision on the purchase of agricultural machinery that is not older than five years for the needs of the agricultural economy.

Apart from this basic conclusion, the following conclusion can be highlighted, that there is a strong influence between the three analyzed influencing factors on the conditions of procurement of agricultural machinery, in relation to cases where marketing was used by the advisory service for agriculture, i.e. in cases where there was no direct marketing activity regarding the possibility of using IPARD-1 in order to manufacture agricultural machinery.

Thirdly, the results indicate that the obtained T-values differ significantly in cases of no marketing (the value ranged from 15,253 to 25,455), but in the case of applying marketing in relation to the purchase of agricultural machinery, that interval would be even higher (within an interval of 17,331 to 31,456.) which points to the existence of high significance between the analyzed factors and the application of marketing that promotes the purchase of agricultural machinery through IPARD-1 measures that are foreseen in the business of legal entities in the Republic of Serbia.

CONFLICT OF INTEREST

None is declared.

REFERENCES

[1] Arnautović, I., Davidov, T., Nastić, S., Popović, S. 2022. Značaj donošenja racionalne poslovne odluke top menadžmenta u poljoprivrednim preduzećima u Republici Srbiji, *Poljoprivredna tehnika*, vol. 47(3), pp.1-8.

[2] Bakmaz, O., Dragosavac, M., Popović, D., Brakus, A., Pajović, I., Turčinović, Ž., Radaković, M., Popović, S. (2024). The significance of real financial reporting of agricultural mechanism in relation to the making of management decisions of individual farms and medium-sized agricultural enterprises, *The Journal "Agriculture and Forestry*", 71(1), pp. 171-184.

[3] Popović S, Jovin S, Đuranović D, Popović V, Filipović V, Munitlak-Ivanović O, Grublješić Ž., Mijić R. 2017. The Importance of Planting Pot Marigolds (Calendula officinalis L.) in degraded public spaces from the agro-ecological and economic perspective. *Contemporary Agriculture*, Vol. 66(1-2), pp. 27-31.

[4] Arnautović, I., Davidov, Tatjana., Nastić, Sanda, Popović, S.2022. Značaj poslovnog odlučivanja top menadžmenta u poljoprivrednim preduzećima koja koriste praktičnu primenu novih pristupa softverskih rešenja IT sektora u Republici Srbiji, *Poljoprivredna tehnika*, vol. 47, br.2, pp. 51-57.

[5] Popović, S., Laban, B., Vukasović, D., Ivić, M., Nastić, S., Popović, V. 2018. Internal and external audit as a factor in improving the management of the Agricultural enterprise, *Poljoprivredna tehnika*, vol. 43(4), pp. 8–12.

[6] Bakmaz, O., Dragosavac, M., Brakus, A., Radaković, M., Arnautović, I., Samardžić, V., Krstajić, G., Popović, S. 2024. Financial security and invoicing in management of public enterprises whose founders are local self-government units, example Republic of Serbia, *Lex localis-Journal of Local Self-Government,* 22(2), pp. 198-218.

[7] Radović, M., Vitomir, J., Laban, B., Jovin, S., Nastić, S., Popović, V., Popović S. 2019. Management of joint stock companies and farms by using fair value of agricultural equipment in financial statements on the example of IMT 533 Tractor, *Economics of Agriculture*, Vol. 1, pp. 35-50.
[8] Tomas-Miskin S., Vitomir, J., Popović, S., Vitomir, G. 2022. Decision-making of Top Management and Internal Audit on the Issue of Archiving Documentation in Companies Founded by Local Government Units in the Republic of Serbia, *Lex Localis – Journal of Local Self-Government,* Vol. 20(4), pp. 889 – 995.
[9] Radović, M., Vitomir, J., Popović, S. 2021. Kretanje dokumentacije u sklopu revizijskog izveštavanja top menadžmenta poljoprivrednog preduzeća, *Poljoprivredna tehnika,* vol.46, br.1, pp. 47-53.
[10] Radović, M., Vitomir, J., Popović, S., Stojanović, A. 2023. The Importance of Establishing Financial Valuation of Fixed Assets in Public Companies whose Founders Are Local Self-Government Units in the Republic of Serbia, *Enginering Economics*, Vol. 34(3), pp. 246-255.
[11] Prodanović, R., Ćirić, M., Ignjatijević, S., Đurić, K., Vapa-Tankosić, J., Egić. S. 2021. Analiza faktora od uticaja na konkurentnost domaćeg meda. *Ekonomija – teorija i praksa*, 14 (4); pp. 73-93.
[9] Radović, M., Vitomir, J., Popović, S. 2021. Impact of internal control in enterprises founded by local self government units: the case of Republic of Serbia, *Inžinerine ekonomika-Engineering Economics*, Vol. 32(1), pp. 82–90.
[10] Bakmaz, O., Bjelica, B., Vitomir, J. 2023. Application of software solutions in companies that strive to achieve increased financial stability in their regular business, *Temel-IJ*, 7:1, pp.13-20.
[11] Popović, S. (2018). Modeling a strategic top management in the importance of the management of the finance companies established for the establishment of fer value, *Poljoprivredna tehnika*, vol. 43, br.2, pp.11–16.
[12] Popović, S., Vitomir, J., Tomaš-Miskin, S., Davidov, T., Nastić., S., Popović, V., Popović, D., Vitomir, G. 2021. The importance of a realistically determined amount of tax on property rights relating to the ownership of agricultural land in the Republic of Serbia adopted by tax authorities of local Self-Government units, *Ekonomika poljoprivrede*, Vol. 4, pp. 1029-1042.
[13] Jokić Maja, Popović Dragna, Popović, S., 2020. Značaj pripreme revizijskog izveštaja za top menadžment poljoprivrednog preduzeća, *Poljoprivredna tehnika*, vol.45, br.2, pp. 21-27.
[14] Radović, M., Vitomir, J., Laban, B., Jovin, S., Nastić, S., Popović, V., Popović S. 2019. Management of joint-stock companies and farms by using fair value of agricultural equipment in financial statements on the example of IMT-533 tractor, *Economics of Agriculture*, Vol. 1. pp. 35-50.
[15] Vitomir, J., Radović, M., Popović, S. 2021. The Effect of Public Finance Control on the Improvement of Work of Internal Auditors in Enterprises Founded by the Local Self-government Units on the Example of the Republic of Serbia, *Lex localis - Journal of Local Self-Government*, Vol. 19(2).
[16] Čolović, M., Đuranović-Miličić, J., Gligović, D., Arnautović, I., Nastić, S., Popović, S. 2024. Joint investments of the real economy and healthcre institutions in the Republic of Serbia, *Ekonomija Teorija i praksa*, 17(3), pp. 97-108.

NABAVKA POLJOPRIVREDNE MEHANIZACIJE PUTEM IPARD-1 I PRIMENA MARKETINGA U CILJU OBJAŠNJENJA PROFITABILNOSTI ULAGANJA PUTEM SAVETODAVNE SLUŽBE

Srđan Jovanović[1], Snježana Đokić[2], Slobodan Popović[3*]

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Abstrakt: Studija je pokazala važnost marketinga u pogledu donošenja poslovne odluke o nabavki poljoprivredne mehanizacije koja nije starija od pet godina za potrebe poljoprivrednog gazdinstva.

U ovoj studiji autori su utvrdili da postoji snažan uticaj kako između tri faktora uticaja na uslove nabavke poljoprivredne mehanizacije (postojanje mogućnosti povraćaja sredstava u iznosu od 60-70%), tako i u odnosu na slučajeve da se koristio marketing od strane savetodavne službe za poljoprivredu, odnosno kada nije postojala direktna marketinška aktivnost po pitanju mogućnosti korišćenja IPARD-1, u cilju nabavke poljoprivredne mehanizacije.

Pored toga, ustanovili smo da se (T-vrednost) značajno razlikuju u slučajevima ne korišćenja marketinga i njena vrednost se kreće od 15.253 do 25.455, da bi u slučaju primene marketinga u odnosu na nabavku nove poljoprivredne mehanizacije taj interval bio još viši, odnosno značajnost je još veća i kreće se od 17.331 do 31.456.

Ključne reči: *IPARD-1, poljoprivredna mehanizacija, marketing, povrat novca.*

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RIVER BASINS DEVELOPMENT IN NIGERIA: A REVIEW

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Abstract: Basin water development is vital in development of basin water resources. It involves the management, utilization, and conservation of water resources within a particular geographical area called basin. The basin water development involves different approaches for efficient and effective management of water resources within the basin. These approaches include; Integrated water management, Sustainable Resource Use, Conflict Resolution, Ecosystem Preservation, Flood Control and Mitigation, Climate Change Adaptation, Economic Development, Improved Water Quality. If these are approaches are implemented or the basin is developed to suit these approaches, there will be adequate, efficient and effective utilization of water resources in the basin among different users.

Keywords*: Water resources, River basin, development, management, Nigeria, policies*

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INTRODUCTION

Basin water development refers to the management, utilization, and conservation of water resources within a specific river basin or watershed. It involves various strategies, policies, and projects aimed at ensuring sustainable access to water for various purposes like agriculture, industry, urban consumption, and environmental conservation within that particular geographical area.

A river basin is defined as a portion of land drained by a river and its tributaries. It encompasses the entire land surface dissected and drained by mainly streams and creeks that flow downhill into one another. In this paper, a river basin is used to mean the portion(s) of land drained by a river, streams and creeks. The river basin development for water resources involves a set of rules in the form of programmed that takes special account of a particular region called basin and itemizes aims and objectives of water development in the basin for improving the levels of living of the people in that area. [1] attempted to enumerate those aspects of river basin water development, which in view of a programme for national, economic and social development, strive at a close integration with the structures, features and variables of the development process in Nigeria. These include: the regional population in relation to the area of land available and land water relationship, the demographic in relation to water demand and job opportunities as well as the growth of productive enterprises now and in the future, the structure of government in relation to administrative and political process in the region. And in developing river basin for effective and efficient management of water resources has some basic approach such as; Integrated water management, Sustainable Resource Use, Conflict Resolution, Ecosystem Preservation, Flood Control and Mitigation, Climate Change Adaptation, Economic Development, Improved Water Quality [2]. This writeup aims at reviewing basin water development; its scope considers social, economic, and environmental aspects of basin water development to ensure equitable and sustainable water management for current and future generations.

History of river basins development in Nigeria

The evolution of river basin development in Nigeria dates to the colonial era. The idea of harnessing Nigeria's rivers and their basins for agro-allied uses is very in Nigeria is traced to the era of British colonial administration in Nigeria. The British colonial government as at the late 1940s took special interest in the utilization and development of the river basins especially in northern Nigeria [3]. This was because of the acute shortage of rainfall in the northern part of the country, which hampered farming activities. The colonial development welfare fund made special provisions for this. For instance, during the colonial epoch, irrigation schemes were carried out at Yau on the Yobe River, at Ebiji, east of Maiduguri, Warno in Sokoto, in Kano and Smaller ones around Jos [3].

Njoku clearly observes that the British colonial authorities in Nigeria were inspired by the Tennessee Valley Authority in the United States of America which had prior to 1947 helped to revolutionized agricultural production in the United States through the use of river basins.

As a result of this, in 1947, the northern Nigeria colonial administrators through Colonial Development Welfare Fund (CDWF) voted special fund for commerce preliminary investigation into how best to develop the Sokoto-Rima basin for overall agricultural, techno-industrial development.

The economic gluts and the effects of war on the British economy and finances of the colonial economies caused further delay in the development of river basins in Nigeria.

In 1963, the Lake Chad Basin Commission as established. Works started on the Lake Chad Basin and the Sokoto River Basin during 1973-1974. The oil boom, which enhanced the revenue base of Nigeria, helped the federal government to create both legislative and institutional framework upon which the activities of RBDAs in Nigeria will be coordinated and developed for national growth and development [4].

In this perspective, [3] therefore, argued that this further led to the promulgation of decree No 73 in 1973 which extended the RBD project nationwide thus, following promulgation of the decree; eleven (11) RBDAs were established. There was additional creation of the Sokoto Rima Basin authority which brings the total number of RBDAs to twelve (12). Each authority was placed in charge of a designated area, though the demarcation sometimes followed geo- political rather than logical geomorphic profile.

These river basins and their headquarters are listed below;

1. Anambra- Imo River Basin Development Authority- Owerri
2. Benin Owena River Basin Development Authority- Benin
3. Chad River Basin Development Authority – Maidugri
4. Cross River Basin Development Authority – Calabar
5. Hadeji-jama-are River Basin Development Authority – Kano
6. Lower Benue River Basin Development Authority-Makurdi
7. Lower Niger River Basin Development Authority– Ilorin
8. Niger delta River Basin Development Authority – Port Harcourt
9. Ogun-Osun River Basin Development Authority
10. Upper Benue River Basin Development Authority Yola
11. Upper Niger River Basin Development Authority –Abeokuta
12. Sokoto Rima River Basin Development Authority Sokoto

In order to facilitate rapid economic development of Nigeria through an integrated planning and management of Nigerian river basins, the authorities had the following mandate in their various operational areas;

1. Construction of dams and boreholes for irrigation and rural water supply
2. Large-scale mechanized clearing and cultivation of various land forms
3. Rural electrification and construction of feeder roads
4. Establishment of agro-service centres, with tractor hires services
5. Large scale multiplication of improved seeds for distribution to farmers
6. Large scale rearing of improved livestock and poultry for distribution to farmers
7. Establishment of grazing reserves for nomadic cattle breeders;
8. Establishment of large scale a forestation scheme and
9. Training of junior staff for oral development projects
10. Contribute to overall national security through food production and distribution governs for enhancing natural food self-sufficiency.

Nigeria is endowed with enormous water resource as is evident in the volume of rainfall, surface and underground water deposits [5.6] and yet, the gap between water needs and water supply appear to be widening [7].

Water resources development in Nigeria is threatened by both natural factors such as outcomes of climate change and hydrological extremes, and anthropogenic factors such as pollution of water bodies with industrial wastes, oil spillages, and salinization of surface and ground waters through irrigation and fertilizers [6].These natural and anthropogenic threats to water sources trigger variations in the physiochemical and biological characteristic of the water, ultimately impairing the quality of the water [7]. The dearth in the water management and supply system in Nigeria has led to many citizens resorting to self-help and exploiting the underground water resources in an unstructured and uncoordinated, and unsustainable manner [8]. As noted by [9], over 60% of Nigerians with access to drinking water now get it from underground sources.
He also noted that sustainable groundwater use in Nigeria is challenged by funding, weak institutions, poor data management system, poor implementation of groundwater exploitation regulation, in addition to hydrological factors. Many private business ventures have emerged from the decadence of water management and supply Nigeria.

For most poor and rural dwelling citizens, access to clean water supply has continued to be a challenge. As contended by [10], the dependence on private for-profit water ventures to meet the water needs of the population is unsustainable.

This further indicates the failure of policy. The uncoordinated exploitation of ground water may have other consequences, considering that geological and other anthropogenic conditions may affect the quality of the water. Some of the private individuals and business concern usually don't have the capacity to treat the water before making it available for human consumption. This is the case in most urban areas in Nigeria, where groundwater quality is affected by the geochemistry of the environment, rate of urbanization, industrialization, landfill and dumpsite leachates, and heavy metals [11,12]. Other fundamental challenges to water resources in Nigeria include wetland
degradation [13], climate change [14], scarcity, conflicting demands among others.

Frameworks and Approaches to Basin Water Development

In recent years, there have been substantial changes in water management approaches as a result of the emergence of new paradigms. Traditional approaches were essentially hydro-centric or single-sector (water) oriented. Consequently, the river basin or groundwater province was viewed as a complex physical system based on complex interrelationships between the hydrological and geomorphologic characteristics of the basin and its rivers and streams. Common in the 1930s to 1960s and favored by water engineers and water economists, this approach viewed the basin as a resource system whose waters were to be exploited for economic development. This approach emphasized the determination of maximum possible yield and the development of mechanisms for the most effective water allocation between users. It also served as the impetus for significant water resources development projects, such as the Hoover Dam—an icon of an era dedicated to dam building and irrigation expansion. Highly scientific methods and technological innovation were the driving forces behind this single-sector approach, which sought to maximize available yield from river basins and watersheds.

As evidenced in the work of the Tennessee Valley Authority and the U.S. Army Corps of Engineers in the US, the Nagarjuna Sagar Dam project in India, and the Snowy Mountains Scheme in Australia, more complex approaches promoted multi-objective development of water resources systems, including recreation, hydropower, navigation, and irrigation development.

The ecological and ecosystems approaches to water resources management, which were a product of the environmental movement of the 1970s, questioned the single (and multi-) objective approach and its strong development emphasis. The reality was that the traditional paradigm ignored the more diverse range of resource use features of river basins that interact to create the so-called "wicked" problems of environmental management and sustainable water resources management. The new paradigm recognized river basins as large, complex, integrated ecological systems.

The term "ecosystem approach" served as a corollary for the integrated approach. Using this critical lens, the watershed was seen as an integrated ecological system in which human impacts were but one component of the functioning of ecosystems.

[15] recognized that the challenge of this integrated approach was its interpretation. He maintained that its advocates had for too long interpreted the ecosystem approach as synonymous with a comprehensive approach, in which attention is given to all components and linkages in a system. When a comprehensive approach is taken, there is a high probability that the period of time required to complete an analysis will be very long, thus resulting in a final plan that is no more than an obsolete historical document. Mitchell's interpretation of an integrated approach involves a more selective or focused perspective. Rather than focusing on all the components and connections in a system, it considers only those components that—on the basis of knowledge from all stakeholders (acquired through focus groups or other forums involving people, ranging from technical analysts to long-term residents)—are judged to be the key drivers of variability in the system [16]. Both a comprehensive and an integrated interpretation are consistent with an ecosystem approach, but the latter is more likely to produce a practical output.

Integrated Water Management

Basin water development focuses on an integrated approach to managing water resources within a particular geographic area. It considers the interconnectedness of surface water, groundwater, and their interactions within the basin. Integrated water resources management (IWRM) has been proposed and is now practiced as the new method of water management. It is an approach to land and water resources planning and management that encourages participants to consider a wide array of social and environmental interconnections. It extends beyond traditional, multi- purpose natural resources management to address societal goals and ecosystem functioning. The term IWRM implies the inclusion of a full array of physical, biological, and socioeconomic variables involved in managing a region for environmental values and human use. Many agency natural resource managers and academics have supported planning and managing water and related land resources on a watershed (catchment, river basin) basis and the approach is now being widely adopted [16-23].

IWRM extols the use of integrated, cross-sectoral, and coordinated approaches to water resources management across time and space as well as the river basin scale.

IWRM uses co-management but is fraught with the classic problems of commonly managed resources:
differing interpretations of property rights, conflicts over use, spatial and temporal variations in access to water, susceptibility to hazards of water surpluses or deficits, lack of ongoing financing when other spending (military, health, education) consumes public service delivery budgets, and others.

Despite these problems, IWRM provides mechanisms for meeting top-down with bottom-up management. In any geographical setting, "entry points" for success in IWRM need to be crafted, primarily through either improved human and organizational capacity; dedicated and sustained funding that employs cost-sharing; water visioning, not just ownership of the "commons" problem but also covenants of mutual responsibility and self-responsibility; or building leadership skills.

What works in one location may not work elsewhere. In practice, IWRM must bring together a diverse array of people who have a "stake" in a system if it is to collaboratively manage the activities and impacts. These stakeholders include government entities, community groups, business and industry organizations, and others with a particular concern or interest in water resources management. IWRM must also involve "the public" who also have an interest, albeit less well defined. This participatory approach produces strategies that are more coordinated, more cognizant of interconnections, and more inclusive of the diversity of goals. Furthermore, it increases support and commitment as well as the likelihood of implementation. The conceptual development of IWRM was extended recently by the Global Water Partnership [24]. Moreover, international endorsement of the concept has now been seen at the highest levels, including the 2003 Summit on Sustainable Development in Johannesburg, South Africa as well as the Second (2000) and Third (2003) World Water Forums in Kyoto, Japan. At the latter, "IWRM and the Basin Management Theme" was issued [25].

IWRM and River Basin Management

The nature of hydrological linkages suggests that a river basin forms a natural unit of management for river conservation or other purposes, especially in sub-humid, temperate, tropical, and equatorial hydrological regimes. Rivers are significant areas within watersheds. They are intimately linked to the land systems that surround them. They act as hydrological conduits, receiving excess water from precipitation, infiltration, and groundwater movement and transferring water across the landscape to watershed outlets, such as rivers, lakes, estuaries, and oceans. Thus, the ecological health of a river system reflects the ecological health of the land systems in the river basin and indicates the impact of upstream land management practices on ecological processes.

A recent statement on river basin governance captures the importance of rivers and river basin management. The expert group statement on Integrated River Basin Management for the Second World Water Forum and Ministerial Conference in the Hague, 2000, maintained that sustainable river basin management required proper study, understanding, and effective management within the context of social, economic and environmental resources. This study should recognize that water management at the basin scale must be understood systemically—recognizing conjunctive uses, aquatic ecosystem needs and upstream-downstream relationships.

In view of regional differences, a blueprint for river basin management was not given in this report, but they provided recommendations and guidelines for sustainable river basin management, focusing on:

1. Basin-wide planning: Basin-wide planning should balance all user needs for water resources, in the present and the long-term, and it should incorporate spatial developments. Vital human and ecosystem needs have to be given special attention.
2. Participation in decision-making: Local empowerment as well as public and stakeholder participation in decision-making will strengthen river basin management.
3. Demand management: Demand management has to be part of sustainable water management. Managing the demand for water is more likely to achieve sustainable use than is continual expansion of water supplies.
4. Compliance: Compliance monitoring and assessment of commitments under river basin

Sustainable Resource Use and Sustainable Development:

Sustainable Resource Use emphasizes sustainable utilization of water, ensuring that current needs are met without compromising the ability of future generations to meet their own needs. This involves balancing water extraction for various purposes while maintaining ecological balance and minimizing environmental impacts.

Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [26]. As the world continues to explore economic prosperity, sustainable development goals seek to mainstream the environmental interest of future generations in the economic activities of the present generation. Sustainable development debates have largely centered around the effect of economic activities and industrialization on the environment [27-28]. The goal six of United Nations 2030 agenda for sustainable development, aims at ensuring availability and sustainability of water and sanitation for all.

Scholars like [29-30], have variously explored issues of water management and security for sustainable development. The significance of water resources in developing countries, more so in sub-Sahara Africa cannot be overstated. The depletion of water bases like rivers and lakes calls for an efficient management and exploitation of the resource. Thus [29], held that sustainable development requires integrated multi-sector approach which should incorporate hydrological and non-hydrological components such as the environment, base of the economy, character of socio-cultural and institutional subsystems. [30] noted that transboundary nature of water basins, variability of climate and rainfall, water scarcity, water pollution, environmental degradation and increasing demand are some of the features necessitating efficient water resources management in Africa. The role of water in sustainable development policies is fundamental. Thus, water security issue is a global one that affects all, requiring an interconnected response framework that should be global in design, embodying within it, a variety of national and regional responses [31].

Climate Change Adaptations

The effects of climate change and variability such as rising temperature and changes in rainfall are undeniably clear, with impacts already affecting ecosystems, biodiversity,

and people [32]. Africa is among the most vulnerable regions in terms of the impacts of climate variability and change (Intergovernmental Panel on Climate Change [33-34]. The high vulnerability of Africa to the impacts of climate variability and change is also attributed to its low adaptive capacity [36].
The projected climate change will have far-reaching, negative impacts on the availability of water resources, food and agricultural security, human health, tourism, coastal development, and biodiversity [37].

Stakeholders and Governance

Effective water management and governance within a basin require collaboration, coordination, and mutual understanding among these diverse stakeholders to address challenges like water scarcity, pollution, equitable access, and climate change impacts. These stakeholders include the following;

1. Governments: They play a crucial role in water management through policy creation, regulation, and enforcement. National and local governments develop water laws, allocate water rights, and establish frameworks for water resource management. They often provide funding for infrastructure projects such as dams, irrigation systems, and water treatment facilities. Government agencies also monitor water quality, set standards, and address issues related to water scarcity, pollution, and equitable distribution. Poor governance exacerbates water stress and amplifies the negative impacts of extreme events like flooding and drought. Lack of investment in water allocation and infrastructure, insufficient institutional and human capacity, or lack of political will to satisfy the range of demands for available water, can lead to economic water scarcity, where there are an inefficient and inequitable distribution of water resources, even if there is physical abundance of water. If mounting physical and governance-related pressures on freshwater resources are not addressed, some regions across the world could see their economic growth rates decline by around six percent of their gross domestic product by 2050 [37]. With implications for national and regional security. Improving water resource governance through WRM is therefore critical for building the resilience of systems and people reliant on water supplies who will see dramatic climate-related shifts over the next few decades.
2. Communities: Local communities are directly impacted by water management decisions. They use water for various purposes like agriculture, drinking, sanitation, and industry. Involving communities in decision-making processes ensures that their needs and concerns are considered. Community participation often occurs through public consultations, community-based initiatives for water conservation, and education programs to promote responsible water usage.
3. Non-Governmental Organizations (NGOs): NGOs play a vital role in water management by supplementing government efforts. They often work on the ground, implementing projects related to water conservation, education, and advocacy. NGOs collaborate with communities, governments, and other stakeholders to address specific water-related issues such as access to clean water, sanitation, watershed management, and climate change adaptation.

They also raise awareness, conduct research, and provide technical expertise to support sustainable water management practices.

4. Private Sector: Businesses and industries are significant water users. They have a role in sustainable water management by adopting efficient water use practices, investing in technologies for water conservation, and adhering to regulations on water pollution. Some private entities also engage in partnerships with governments and NGOs for community-based projects that aim to improve water access and quality.
5. Academic and Research Institutions: These entities contribute to water management through research, innovation, and knowledge dissemination. They conduct studies on water-related issues, develop technologies for water treatment and conservation, and train professionals in the field of water resource management.
6. International Organizations: Bodies like the United Nations, World Bank, and regional organizations often facilitate cooperation among countries that share transboundary water resources. They provide technical assistance, facilitate negotiations, and support the development of agreements and treaties for equitable and sustainable water use among different nations within a basin.

Conflict Resolution

As water resources are shared among various stakeholders including communities, industries, and agriculture, conflicts over water allocation and usage can arise. Basin water development provides a framework for equitable distribution and effective conflict resolution mechanisms among these stakeholders. The continued water insecurity has been generally attributed to water governance crises partly manifested in the form of increased water-related conflicts; failure to incorporate peacebuilding into the development and implementation of water projects; lack of conflict resolution mechanisms especially at a local level; and poor operation and maintenance of the water infrastructure [38-40]. Cognizant of the widely documented vicious circle of water governance challenges, local water conflicts and lack of conflict resolution mechanisms have in recent years been highlighted as key governance aspects, challenging efforts to achieve water users' cooperation towards sustainable water security by most governments in developing countries [41-43].

More still, there is fear that increased competition will escalate water-related conflicts among users and actors within as well as among different sectors. Hence, greater efforts are needed to promote water-related conflict transformation and peace building in water development endeavors as a means of preventing and mitigating conflicts at all levels of governance. As a result, tensions may subside, and a renewed sense of communal dignity and cooperation may reign [45].

The term "water-related conflicts" as used in this article, refers to conflicts arising between two or more parties holding competing claims over water resources allocation or their use [46]. I use the term conflict to include a range of patterns of interaction among stakeholder groups at different levels of water governance such as national, district, community, and village levels.

This extends from short-term confrontations among competing resource users where violence is implicit, to sustained and explicit violent clashes involving diverse actors in the water sector such as local end users; private, civil society, donors, and state actors. Therefore, in the context of this article, a water event is considered conflictual if one or more parties are discontented with service provision including water quality, quantity, management, location, and distance to the water source or if one's access rights are challenged, for example, denied water or non-existence or non- functionality of the water infrastructure [47-48].

Ecosystem Preservation

Healthy river basins are crucial for supporting diverse ecosystems. Effective basin water development aims to protect and restore natural habitats, preserving biodiversity and ensuring the sustainability of ecosystems that rely on these water sources. Ecosystem services play a crucial role in the management of river basins, which are vital for sustainable development. Such roles are, Water Provision, Water Purification, Flood Regulation, and Bio-diversity Conservation.

Flood Control and Mitigation

Proper management of water resources in a basin includes measures to control and mitigate the impacts of floods. This might involve constructing dams, reservoirs, and implementing land-use planning strategies to reduce the vulnerability of communities to flooding.

Economic Development

Sustainable water management is essential for economic development. It supports agriculture, industry, and urban growth by ensuring reliable water supply for various purposes. Additionally, it can promote eco-tourism and recreational activities associated with well-maintained water bodies.

Improved Water Quality

Managing water resources at a basin level involves monitoring and improving water quality. Controlling pollution sources, implementing wastewater treatment, and maintaining healthy aquatic ecosystems contribute to better water quality for consumption and ecosystem health.

SOLUTIONS AND RECOMMENDATIONS

Some policy interventions and changes that could help improve basin water management in Nigeria include:

1. **Integrated Water Resource Management (IWRM):** there should be Implementation of policies that adopt an integrated approach to managing water resources.

This involves considering the various uses of water (agriculture, industry, domestic), environmental conservation, and the needs of different stakeholders within the basin.

2. **Water Conservation Initiatives:** there is need to encourage and incentivize water conservation practices among industries, agriculture, and households. This might involve promoting efficient irrigation techniques, fixing leaks in water supply systems, and implementing water-saving technologies.
3. **Stakeholder Engagement and Participation:** there is need to ensure the active involvement of all stakeholders—local communities, industries, agricultural sectors, and government bodies—in decision-making processes regarding water management. This could be done through public consultations, community meetings, and participatory forums.
4. **Ecosystem Protection and Restoration:** the development and enforcement of policies aimed at protecting and restoring ecosystems within the basin is very essential. Healthy ecosystems contribute to water quality and quantity, and measures such as afforestation, wetland restoration, and erosion control can significantly impact water resources positively.
5. **Water Pricing and Economic Instruments:** Policies that reflect the true value of water should be implemented. This could involve setting up pricing structures that encourage responsible water use, especially in sectors that are heavy water consumers, while ensuring access to water for basic needs.
6. **Climate Change Adaptation Strategies:** Developing strategies to address the impacts of climate change on water resources within the basin needs not be overemphasized. This might involve investing in resilient infrastructure, water storage solutions, and drought/flood management plans.
7. **Transboundary Cooperation:** If the basin spans across multiple regions or countries, there is need to foster cooperation and agreements among these entities to manage water resources sustainably. This could involve treaties, joint management plans, and shared data for better decision-making.
8. **Technology and Innovation:** The adoption of innovative technologies for water purification, desalination, wastewater treatment and reused, green infrastructure, blockchain technology and efficient water use is very essential. This might involve providing incentives for research and development in water-saving technologies.
9. **Education and Awareness Programs:** there should be Implementation of educational programs to raise awareness about the importance of water conservation and sustainable management practices among the population. This could be done through schools, media campaigns, and community outreach programs.
10. **Monitoring and Regulation:** there is need to strengthen monitoring mechanisms to track water usage, quality, and environmental impacts as well as develop and enforce regulations that ensure compliance with water management policies, including penalties for non-compliance.

CONCLUSION

This paper assessed water basin development and management in Nigeria. It relates overall challenges of basin water resources development globally. Framework and approaches related to water basin development, where the traditional approach was essentially hydro-centric or single-sector (water) oriented. This approach emphasized the determination of maximum possible yield and the development of mechanisms for the most effective water allocation between users. The ecological and ecosystems approaches to water resources management, which were a product of the environmental movement. "Ecosystem approach" served as a corollary for the integrated approach, the watershed was seen as an integrated ecological system in which human impacts were but one component of the functioning of ecosystems. Basin water development has significance in managing water resources, and is been discuss using various approach such as integrated water management, Sustainable Resource Use, climate change adaptation, Stakeholders and Governance, Conflict Resolution, Ecosystem Preservation, Flood Control and Mitigation, Economic Development, and Improved Water Quality.

It also offers policy interventions and changes that could help improve basin water development and management.

REFERENCES

[1] Olayide, S.O.1980. Perspective in Bennin-Owenna River Basin Development. Ibadan: Ibadan university press.

[2] Onuh, P. A & Bassey, U. I. 2021. Water Resource Management and Sustainable Development in Nigeria: Lessons from Israel. University of Nigeria J. of Political Economy: Vol. 11, pp.48-68.

[3] Onwuka N. Njok, 2001. Economic History of Nigeria, 19th & 20th Centuries, Magnet Business Enterprises in English, pp.1-271.

[4] Adeoti, O. 2010. The Development of River Basin Organizations in Nigeria, Research Journal of Social and Water Management 1 (3-4). pp. 91-100.

[5] Ezeabasili, A.C.C., Okoro B. U., Ezeabasili, A.I. 2014. Water resources: management and strategies in Nigeria. An International Journal of Science and Technology, 3(1), pp.35-54.

[6] Idu, A.J. 2015. Threats to water resources development in Nigeria. Journal of Geology and Geophysics, 4(3), pp.1-10. doi:10.4172/2329-6755.1000205.

[7] Chukwu, K.E. 2017. Pollution of surface water resources in Nigeria. International Journal of Academic Research in Environment and Geography, 4(1), 77–92.

[8] Akpor, O.B., Muchie, M. 2011. Challenges in meeting the MDGs: The Nigerian drinking water supply and distribution sector. Journal of Env. Science and Technology, 4 (5). pp.480-489.

[9] Omole,D. O. 2013) Sustainable groundwater exploitation in Nigeria. Journal of Water, 43(1): pp.5-21.

[10] Obeta, M. C. 2019. Private for-profit rural water supply in Nigeria: policy constraints and options for improved performance, Journal of Water and Land development. No41, pp.101-110.

[11] Ocheri, M. I, Odoma L.A., Umar, N.D. 2014. Groundwater quality in Nigerian urban areas: A Review. Global Journal of Science Frontier Research: h. Environment & Earth Science, Vol.14, Issue 3. pp.34-45.

[12] Olorunfemi, D., Efechuku, U., Esuana, J. 2015. Toxicological Evaluation of Drinking Water Sources in Some Rural Communities in Southern Nigeria after Mycofiltration Treatment. Polish Journal of Environment Studies, Vol. 24(3): pp.1205-1212.

[13] Uluocha, N.O., Okeke, I.C. 2004. Implications of wetlands degradation for water resources management: Lessons from Nigeria. GeoJournal Vol.61, pp.151-154.
[14] Coulibaly N., Coulibaly, T.J.H., Mpakama, Z., Savané, I. 2018. The impact of climate change on water resource availability in a trans-boundary basin in West Africa: The Case of Sassandra. Journal of Hydrology. Vol.5., Issue 1, pp.1-13.
[15] Mitchell, B. 1991. "BEATting" Conflict and Uncertainty in Resource Management and Development. In Mitchell, B. (ed.) Resource Management and Development. Oxford University Press, Toronto.
[16] Hooper, B.P., G. McDonald and B. Mitchell. 1999. Facilitating Integrated Resource and Environ. Management. Journal of Environmental Management and Planning 42 (5), pp.747-766.
[17] Batchelor, C. 1999. Improving water use efficiency as part of integrated catchment management. Agricultural Water Management 40: pp.249-263.
[18] Bellamy, J. A., McDonald, G. T., Syme, G. J. and Butterworth, J. E. 1999. Evaluating Integrated Resource Management. Society and Natural Resources 12: pp.337-353.
[19] Born, S. M. and Sonzogni, W.C. 1995. Integrated environmental management: strengthening the conceptualization. Environmental Management 19: pp. 167-181.
[20] Environmental Protection Agency. 1993. Watershed Protection: Catalog of Federal Programs. EPA, Washington, DC. pp.1-120.
[21] Gonzalez, A. C., Arias, C. 2001. The incorporation of integrated management in European water policy. IAHS Publication. pp. 69-74.
[22] Jonch-Clausen, T. and Fugl, J. 2001. Firming up the Conceptual Basis of Integrated Water Resources Management. 2001. International Journal of Water Resources Development. Vol.17. Issue 4., pp.501-510
[23] Margerum, R., Born, S.M. 2000. A Co-ordination Diagnostic for improving Integrated Environmental Management. Journal of Env. Planning and Management. Vol.43(1). pp.5-21.
[24] Food and Agricultural Organization FAO. 2008. Nigeria. Retrieved from: http://www.fao.org/nr/water/aquastat/countries_regions/nga/printfra1.st
[25] World Water Council, 2003. Integrated Water Resources Management and the Basin Management Theme. Final Statement. Report of the Session: IWRM and River Basin Governance.
[26] United Nations General Assembly. 1987. Report of the world commission on environment and development: Our common future. Oslo, Norway: United Nations General Assembly, Development and International Co-operation: Environment.
[27] Polasky, S., Kling, C. L., Levin, S. A., Carpenter, S. R., Daily, G. C., Ehrlich, P. R., Heal, G. M., Lubchenco, J. 2019. Role of economics in analyzing the environment and sustainable development. PNAS, Vol. 116 (12). pp. 5233-5238. https://doi.org/10.1073/pnas.1901616116.
[28] Bartniczak, B., Raszkowski, A. 2018. Sustainable Development in African Countries: An Indicator-Based Approach and Recommendations for the Future. Sustainability, 11(22), pp.1-23
[29] Kundzewicz, Z.W. 1997. Water resources for sustainable development. Hydrological Sciences Journal, 42(4), pp.467–480. doi:10.1080/02626669709492047.
[30] Mwanza, D.D. 200). Water for sustainable development in Africa. Environment, Development and Sustainability, 5(1/2), pp.95–115.doi:10.1023/a:1025380217316
[31] Biswas, A. K. (1991). Water for sustainable development in the 21st century. International Journal of Water Resources doi:10.1080/07900629108722516 Development, 7(4), pp.219–224.
[32] Vera, C., Barange, M., Dube, O. P, Goddard, L., Griggs, D., Kobysheva, N., Odada, E., Parey, S., Polovina, J., Poveda, G., Seguin, B. and Trenberth, K. 2010. Needs Assessment for Climate Information on Decadal Timescales and Longer. Procedia Environmental Sciences 1: pp.275 - 286.
[33] IPCC (2007). Climate change 2007: the scientific basis. The Fourth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, New York. p. 940.
[34] Fischer, G., Shah, M., Tubiello, F.N. and van Velhuizen, H. 2005. Socio-economic and climate change impacts on agriculture: an integrated assessment 1990 – 2080. Philosophical Transactions of the Royal Society 360. Issue 1463. https://doi.org/10.1098/rstb.2005.1744.

[35] Global Water Partnership, 2000. Integrated Water Resources Management. Technical Advisory Committee Background Paper No.4. pp.1-68. Global Water Partnership: Stockholm
[36] United Republic of Tanzania (URT). 2003. Initial Communication under the United Nations Framework Convention on Climate Change (UNFCCC). Vice President's Office, Dar es Salaam, Tanzania, [ttp:// unfccc.int/resource/docs/natc/tannc1.pdf].
[37] Mugabe, F. T., Chitata, T., Kashaigili, J., Chagonda, I., and Nyagumbo, I. 2010. Modelling the effect of rainfall variability, land use change and increased reservoir abstraction on surface water resources in semi-arid southern Zimbabwe. In: Proceeding of 11th WaterNet WARFSA GWP - SA symposium. (Edited by WARFSA), 27 – 29 October 2010, Victoria Falls, Zimbabwe. pp. 313 - 334.
[38] World Bank Group. 2016. High and Dry: Climate Change, Water and the Economy. Book Water Global Practice. pp.1-55.
[39] Naiga, R. 2020a. Determinants of user satisfaction and the implications on collective-action indemand-driven water governance in rural Uganda. International Journal of Rural Management, pp.1-27. https://doi.org/10.1177/0973005220968957.
[40] Eberhard, R. R., Margerum, K., Vella, S., Mayere, S., B. Taylor, B. 2017. The practice of water policy governance networks: An International comparative case study analysis. Society and Natural Resources, 30(4), pp.453–470.
[41] Global Water Partnership. 2002. Dialogue on Effective water Governance. Global Water Partnership. pp.1-23.
[42] Naiga, R. 2018. Conditions for successful community-based water management: Perspectives from rural Uganda. International Journal of Rural Management, 14(2), pp.1-26.
[43] Taylor, P.L., Sonnenfeld, D.A. 2017. Water crises and institutions: Inventing and reinventing governance in an era of uncertainty. Society and Natural Resources, 30(4), pp. 395–403.
[44] Naiga, R., Penker, M. Hogl, K. 2015. Challenging Pathways to Safe Water Access in Rural Uganda: From Supply to Demand-Driven Water Governance. International Journal of the Commons, 9. pp.237-260. https://doi.org/10.18352/ijc.480.
[45] Gehrig, J., Rogers, M.M. 2009. Water and conflict: Incorporating peace building into water
[46] Organization for Economic Co-operation and Development/Development Assistance Committee (OECD/DAC). 2005. Main streaming conflict prevention: Water and violent conflicts.
[47] Swain, A. 2016. Water and post-conflict peacebuilding, Hydrological Sciences Journal, 61(7), pp.1313-1322
[48] Van Laerhoven, F., Andersson, K.P. 2013. The virtue of conflict: An institutional approach to the study of conflict in community forest governance. International Forestry Review, 15(1), pp.122–135. https://doi.org/10.1505/146554813805927219

FORMIRANJE REČNIH SLIVOVA U NIGERIJI: PREGLED

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Apstrakt: Razvoj i formiranje voda u basenu je od vitalnog značaja za stanje vodnih resursa sliva reka. To uključuje upravljanje, korišćenje i očuvanje vodnih resursa unutar određene geografske oblasti koja se naziva sliv reke.
Razvoj slivnih voda uključuje različite pristupe za efikasno i efektivno upravljanje vodnim resursima unutar sliva. Ovi pristupi uključuju: Integrisano upravljanje vodama, održivo korišćenje resursa, rešavanje konflikata kod upotreb, očuvanje ekosistema, kontrola i ublažavanje poplava, prilagođavanje klimatskim promenama, ekonomski razvoj, poboljšanje kvaliteta vode.
Ako se ovi pristupi implementiraju ili se sliv razvije tako da odgovara ovim pristupima, postojaće adekvatno, efikasno i efektivno korišćenje vodnih resursa u slivu između različitih korisnika reke.

Ključne reči: *vodni resursi, rečni sliv, razvoj, upravljanje, Nigerija, politike*

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EFFECTS OF GOLD MINING ACTIVITIES ON RURAL HOUSEHOLDS' MATERIAL WELLBEING IN OSUN STATE, NIGERIA

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Abstract: This study investigated the effects of gold mining activities on rural households' material wellbeing in Osun State, Nigeria. It described rural households' socio-economic characteristics, the living conditions, their perception and also their level of material wellbeing. A multistage sampling procedure was used for the selection of 415 rural household heads in the mining affected communities (AC) and the non-affected communities (NAC). Data was analyzed using descriptive statistics and independent t-test. Their mean annual household income was 772,320 ± 352800 and 2,682,720 ± 780,360 in the AC and NAC, respectively. Majority (78.1%) of the rural household heads in the AC now made use of borehole for domestic uses owning to high contamination of surface water while half (52.2%) of the NAC respondents were still using community stream or river. The rural household heads in the AC strongly opposed the statement that gold mining activities enhance marketing of agricultural produce (1.55 ± 0.64). Also, the NAC household heads disagreed with the statement that gold mining activities offer alternative incomes sources (1.49 ± 0.71). Virtually all (97.2%) AC household heads had significantly low material wellbeing due to high effects of the gold mining activities on them in contrast to the relatively high (99.5%) material wellbeing in the NAC. In conclusion, gold mining activities jeopardized the material wellbeing of its hosting rural community households. Strict policy-backed regulations should be implemented for the adequate relocation and compensation of rural household heads in gold mining areas.

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Keywords: *Affected communities, non-affected communities, land degradation; perception; rural household heads.*

INTRODUCTION

Mining of mineral resources contribute significantly to generation of more revenue for the government through tax and foreign exchange. It creates rooms for employment opportunities in the host communities. Mining has been known to contribute significantly to national economic development [1]. Because of monetary value of gold in the world market and high demand as industrial raw materials across the globe [2]. Mining of gold has been a focal point in the economic diversification policy of the Federal Government of Nigeria. It is without doubt one of the main economic drivers for many countries in the world [3]. Large scale gold mining operations help in providing employment opportunities, generate income and foreign currency [4] for hosting countries and communities. However, despite all the benefits accrued to mining of gold, most literature established its negative environmental implications such as deforestation; land degradation, pollution of water sources and toxic substances exposure such mercury and heavy metals [5, 6,7].

Coupled with licensed gold mining activities are the persistence activities of artisanal gold miners in Nigeria. Artisanal gold mining activities are mainly characterized with the use of crude or rudimentary tools and techniques and mostly carried out illegally with result in environmental hazards and insecurity [8]. Most Nigerians in the mineral dominated rural areas engage in this type of mining as additional source of income [10] The impact of gold mining activities on the environment cannot be overemphasized. Environmental degradation which is mostly caused by mining gold enhances food insecurity, poverty and agricultural productivity suffered a serious setback [11]. The study conducted by [12] revealed that gold mining activities had led to a significant loss in farm revenue due to destruction of crops, soil degradation and water pollution as well as upsurge of criminal activities in the study area.

Prominent in the literature is that rural areas in developing countries such as Nigeria are usually neglected communities especially in the provision of infrastructural and social amenities, communication facilities, industries and absolutely engaged in farming.
[13] opined that rural area is an area or settlement in which half or more than half the adult male working population is engaged in farming.
Rural households are individuals living together under the control of a head in a lowly-populated areas where major occupation is farming. Rural households in developing countries, particularly in Sub-Saharan Africa, are reported to face a variety of developmental issues, including low purchasing power (poverty), low and poor food consumption (food insecurity and undernourishment), underemployment, and general poor welfare [14] and [15]. These challenges were further exacerbated by the perceived threats of gold mining activities to sustainable livelihoods which invariably affecting the material wellbeing of rural households in the study area. Material wellbeing refers to as the individual's satisfaction and fulfillment obtained from their economic resources [16].

Gold mining project was licensed and began operation in the year 2019 [17] for economic growth and development of the country, State and the hosting rural communities. Adequate use of the proceeds from the project is expected to enable the rural households lived well and satisfied in their communities. However, the rural households are combating the negative effects of gold mining activities such as high level of soil degradation, landscape damage, ground and surface water contamination, flooding, deforestation and destruction of arable and cash crops which consequently resulted in their poor living condition while the gold mining project was acclaimed for enhancing the State's internally generated revenue (IGR) and helping in diversifying the economy of the country. Various studies such as [18, 19, 20, 21], and others have been conducted in the study area on the impacts of gold mining activities but not in relation with material wellbeing of rural households. Therefore, the demographic characteristics (age, sex, marital status, household size, educational level) were described, the living conditions of rural households were examined, the perceived effects of gold mining activities on material wellbeing of rural households was investigated while the rural households' material wellbeing was also described to bridge the gap while no significant difference between the material wellbeing of rural household heads in the AC and NAC was hypothesized.

MATERIALS AND METHODS

Study Area

The study area is Ọsun State, inland state in Southwestern Nigeria having highest gold exploration compared to the other states in the region The state was formed from the Southeast of Oyo State on 27 August, 1991 and has its capital at the city of Osogbo. Of the 36 states of Nigeria, Osun is the ninth smallest in area and nineteenth most populous with an estimated population of above 4 million as of 2022 [22]. It is bounded in the North by Kwara State, in the East partly by Ekiti State and partly by Ondo State, in the South by Ogun State and in the West by Oyo State. There are three Agricultural zones in Osun State namely, Ife/Ijesha, Iwo, and Osogbo. The Ife-Ijesha zone is the most mineral rich with highest gold deposits. Gold mining is replete in many parts of the zone by licensed corporations as well as artisanal mining. There are 10 Local government areas and 2 of these namely Atakumosa East and Atakumosa West LGAs are the most intensively explored. Given this, this study focused on the host communities in these two LGAs as well as the adjoining communities to investigate the gold mining activities on the populace. Characteristically, the two LGAs are rural and the people derive livelihood mainly from agricultural activities. As such, they are dependent on the land resource for their farming as means of sustenance and economy. The advent of mining activities with attendant land degradation effects thus puts pressure on the livelihood and living conditions of the mining areas which are tagged as the affected communities in this study, while other areas not yet explore are referred to as the non-affected communities.

Sampling procedure and Sample size

The study population is the rural household heads in the affected and non-affected communities in the 2 mining LGAs (Atakumosa East and West) of Ife-Ijesha agricultural zone of Osun State.

The five most affected communities are namely Iperindo, Imogbara, Odo – Ijesha, Itagunmodi and Araromi. These communities are prominently explored by the miners, both artisanal and licensed corporations. As such they were purposively selected for the study. More so, neighbouring communities in the same LGs, characteristically about the same in terms of composition, size and infrastructure were purposively selected to serve as basis of comparison of the effects of the mining activities. These non-affected le communities are Ilu Isegun, Orisumbare-loode, Aasa, Odesomi and Balogun). From the total population (N) of 12,545 rural households in these 10 communities, representative sample calculated with Yamane formular (n=384 and approximated to 400) was distributed among the 10 communities based on probability proportion to size (PPS). Eventually a total of 214 and 201 household heads were randomly sampled from the affected and non-affected communities, respectively. Therefore, the total sample size for the study was 415.

Data Collection and Analysis

The instrument used for data collection was a validated interview schedule and reliable with the Cronbach Alpha score of 0.75. How rural households perceived the effects of gold mining activities on their material wellbeing compared to others was measured on a 5 – point Likert type scale "More than almost anyone, More than most people, About average, Less than most people and Less than almost anyone". The responses were scored 5, 4, 3, 2 and 1 respectively. Weighted Mean Score (WMS) was used for ranking of the responses. The material wellbeing of the rural household heads was by transposing the scores of the responses such that the rural household heads responded affected 'More than most people' indicated the lowest material wellbeing while the respondent with affected 'less than almost anyone' indicated highest material wellbeing. The minimum score (25), maximum score (71) and mean score (54.08 ± 7.76) were obtained for rural households' material wellbeing in the AC while in the NAC, the minimum score (19), maximum score (40) and mean score (24 ± 3.12) were obtained. The rural households' material wellbeing was categorized based on the mean score obtained. The rural household heads with below mean scores were categorized as having low material wellbeing in both AC and NAC while the rural household heads with mean score and above were categorized as having high material wellbeing in both AC and NAC. The collected data were analyzed using descriptive tools such as frequency counts, percentages, mean and standard deviation. Inferential tools such as Pearson Product Moment Correlation (PPMC), Chi – square and Independent sample test.

RESULTS AND DISCUSSIONS

Socio-Economic Characteristics of Rural Households

The results of the findings in Table 1., reveal that mean ages of 54.87±10.53 years and 54.35±7.57 years at the AC and NAC, respectively were obtained.

This indicates that higher proportions of the rural household heads in the study area were already ageing and thus old enough to express their mind on the effects of gold mining activities on their material wellbeing in the study area. [23] Omotayo (2020) revealed similar average age category among rural household heads in his study in Southwest, Nigeria. The findings on sex also indicate that majority (72.9% and 71.6%) of the rural households were male headed in both AC and NAC respectively. The high proportion of male headed rural households in the study area might be as a result of the fact that men have more access to productive resources most especially farmland than women. This agrees with earlier reports such as [24] affirming the dominance of males over females as household heads in their separate studies. The findings on the marital status show that in the AC and NAC respectively, majority (78.5% and 71.6%) of the rural households were married.

The mean household size in both AC and NAC were 5.4 ± 1.49 and 8.81 ± 2.41 respectively. The larger household size in the NAC implies that rural household heads have more number of people under them being used as farm labour than in the AC. Moreover, the average years of education in the AC and NAC respectively were 4.79 ± 4.95 and 6.23 ± 3.150 years respectively. The implication of this is that low formal education accessed could affect their decision making on the effect of gold mining activities on their material wellbeing as the higher educational status is expected to be accompanied by better decision making.

1. Results of Socio-Economic Characteristics of rural household heads in AC and NAC

Variables	(AC) Freq %	Mean ± SD	NAC Freq %	Mean ± SD
Age (years)		54.87 ±10.53		54.35 ± 7.59
20 – 40	28 13.1		11 5.5	
41 – 60	120 56.1		168 83.6	
Above 60	66 30.8		22 10.9	
Sex				
Male	156 72.9		144 71.6	
Female	58 27.1		57 28.4	
Marital status				
Single	1 0.5		1 0.5	
Married	168 78.5		144 71.6	
Separated	22 10.3		32 15.9	
Divorced	12 5.6		5 2.5	
Widowed	11 5.1		19 9.5	
Household size		5.4 ± 1.49		8.81 ± 2.41
1 – 4	64 29.9		8.0 4.0	
5 – 8	148 69.2		67 33.3	
Above 8	2 0.9		126 62.7	
Annual income (#)		772,320 ± 352800		2,682,720 ± 780,360
1,200,000 and below	207 96.7		12 6.0	
1,212,000 – 2,400,000	7 3.3		97 48.3	
2,412,000 – 3,600,000	0 0.0		84 41.8	
3,612,000 – 4,800,000	0 0.0		8 4.0	

Source: Field survey (2024).

The living conditions of rural households in the study area

The rural household heads were asked questions on possession of some material items that enhance the living condition as stated in Cummins scale 1997 and adopted by [25].

The responses were analyzed using descriptive statistics. Results in Table 2., show the living conditions of the rural households in the study area.

Analysis on the type of house the rural households were living shows that majority (65.5% and 73.1%) of them respectively in the AC and NAC were living in a - wing apartment, the apartments were personally owned by close to half (48.1% and 46.8%) of them respectively in the AC and NAC while most (90.0% and 83.6%) of the rural households in the NAC and AC, respectively made use of mud block for their building constructions. This might be as a result of the fact that mud or earthen houses are considered to be environmentally friendly and affordable as compared to houses built with concrete or fired clay bricks [26]. Data on roofing shows that most (93.0%) of the rural households' houses have short span aluminum roofing sheet in the NAC while the same materials were used by majority (82.2) of them in the AC. Also, majority (78.1%) of the rural households in the AC were making use of borehole available in their community while half (52.2%) of them were using stream or river water for drinking and domestic use in the NAC. The higher proportion of respondents using the available borehole might be as a result of change in quality of the available water in the AC while the quality of the available water remains intact in the NAC. Firewood happened to be source of energy for cooking by larger percentage (89.5%) of rural households in the NAC while many (65.9%) of them were also using firewood for cooking in AC. Information collected and analyzed on the type of toilet used by the rural households in the study area reveals throwing in the bush. This was indicated by majority (80.1%) of them in the NAC while little above average (55.1%) used the same method to comfort themselves in the AC. Toilet availability has a great influence in the health condition of individuals in society. It is an integral part of building as it determines the environmental wellness and influences the occurrence of water and food borne diseases like cholera, diarrhea and typhoid fever [27].

Fig. 1.1. Building structure affected by blasting in the AC
Source: Field survey (2024).

Fig. 1.2. Building structure in the NAC
Source: Field survey (2024).

Fig. 1.3. Rural water contaminated by gold mining activities in the AC
Source: Field survey (2024).

Fig. 1.4. Building structure in the NAC
Source: Field survey (2024).

Table 2. Living condition of rural households in the study area, n = 415

Material wellbeing questions / statements	Housing features	AC (n=214)		NAC (n=201)	
		Freq.	%	Freq.	%
Where do you live?	A room	4	1.9	1	0.5
	A room and parlour	62	29.0	39	19.4
	A wing	139	65.0	147	73.1
	A flat / apartment	9	4.2	14	7.0
	A duplex	-	-	-	-
Type of ownership of the building	Inherited	32	15.0	69	34.3
	Family / Friend's house	27	12.6	2	1.0
	Rent	52	24.3	36	17.9
	Personally own	103	48.1	94	46.8
	Hut	-	-	1	0.5
Type of materials used for building	Mud block	179	83.6	181	90.0
	Stored rain water	2	0.9	2	1.0
Sources of drinking water	Stream / River	2	0.9	105	52.2
	Well	42	19.6	33	16.4
	Tap	-	-	-	-
	Borehole	168	78.5	61	30.3
Sources of household energy	Firewood	141	65.9	180	89.5
	Charcoal	61	28.5	15	7.5
	Kerosine	-	-	-=	-
Type of toilet used	Throwing or burying in the bush	118	55.1	161	80.1
	Public pit toilet	1	1.9	1	0.5
	Residential pit toilet	65	30.4	21	10.4
	Semi – water closet	14	6.5	9	4.5
	Water closet	13	6.1	9	4.5

Source: Field survey (2024).

Perceived Effects of gold mining activities on material wellbeing of the rural households

How the rural households perceived the effects of gold mining activities on their material wealth compared to others was shown on Table 2. The result reveals that respondents in the AC ranked effects of gold mining activities on arable land and cash crop land 1st with the mean values of 4.45± 0.81 and 4.45 ± 0.86 respectively. There was a similar ranking (1st) of the effect of gold mining activities on arable land and cash crop land with mean scores of 1.02 ± 0.28, 1.02 ± 0.28 and 1.02 ± 0.28 respectively in the NAC. The result of this finding implies that the rural household heads felt high effects of gold mining activities on their material possession such as arable land and cash crop land more than most people in the AC but in the NAC, the rural household heads felt the effect of gold mining activities less than almost anyone because no mining is taken place there. The resultant implication of this in the AC might be persistence poverty and food insecurity which might negatively impact their material wellbeing. The buildings of rural household heads were impacted next (ranked 2nd) with the mean score of 4.29 ± 1.02 in the AC while in the NAC, the effects of gold mining on the rural buildings was ranked 1st with the mean score of 1.02 ± 0.28.

This indicates that the rural household heads in the AC were more impacted than most people by the gold mining activities effects on their building while the NAC rural household heads' building were less affected than almost anyone. The higher impact on the AC buildings might be consequent on gold mining activity known as blasting. Blasting results into cracking and dilapidation of most of the buildings in the AC and this might force most of the rural households out of their comfort zones. Movement of vehicles (ranked 3rd) in the AC (4.10 ± 1.08) became more difficult for rural household heads because of pits from gold mining while the view was also similar in ranking (3rd) for the NAC (1.01 ± 0.21) rural household heads.

Furthermore, the rural household heads' forest land, livestock, processing equipment, farm tools / equipment and use of ICT tools were ranked (4th, 5th, 6th, 7th and 8th respectively with Mean and Standard Deviation closer to 4.0) in the AC while in the NAC, the forest land, livestock, processing equipment, farm tools / equipment and use of ICT tools were all ranked 3rd with Mean and Standard Deviation of 1.0. This finding also shows that the rural household heads in the AC faced high effects of gold mining activities on the listed material items more than most people while in the NAC, the rural household heads felt the effect of gold mining activities on the material items less than almost anyone. In a nutshell, as the rural household heads felt more effects of gold mining activities on all the material items considered in the study, the material wellbeing of the rural household might be jeopardized and the likelihood of being demoralized from continue their livelihood activities in the area is close to certainty. Therefore, there is need for consideration of the general wellbeing of the rural households in the gold mining affected areas.

Table 3. How rural households perceived the effects of gold mining activities on their material wealth compared to others

Material items	AC		NAC	
	Mean ± SD	Rank	Mean ± SD	Rank
Gold mining activities affect arable land	4.45 ± 0.81	1st	1.02 ± 0.28	1st
Gold mining activities affect cash cropland	4.45 ± 0.86	1st	1.02 ± 0.28	1st
Gold mining activities house / building structure	4.29 ± 1.02	2nd	1.02 ± 0.28	1st
Gold mining act.s affect vehicles movement on the farm	4.10 ± 1.08	3rd	1.01 ± 0.21	3rd
Gold mining activities affect forest land	3.88 ± 1.32	4th	1.01 ± 0.21	3rd
Gold mining activities affect livestock	3.72 ± 1.40	5th	1.01 ± 0.00	3rd
Gold mining activities affect processing equipment	3,69 ± 1.35	6th	1.0 ± 0.00	3rd
Gold mining activities affect farm tools / equipment	3.67 ± 1.40	7th	1.0 ± 0.00	3rd
Gold mining activities affect the use of ICT	3.39 ± 1.48	8th	1.0 ± 0.00	3rd

Source: Field survey (2024).

Level of material wellbeing of the rural households

Results in Table 4., show the material wellbeing level of the rural households. It was revealed that virtually all (97.2%) of the rural household heads in the AC had low material wellbeing due to high effects of the gold mining activities while it was high (99.5%) in the NAC since they were not affected by the mining activities.

With this low level of material wellbeing of the rural household heads that are primarily in production of food and cash crops might relocate from the areas. This might result in food insecurity and high rate of poverty for those that remain in the area and attainment of Sustainable Development Goals (SDGs) objectives one, two, three and six (Eradicate poverty, banish hunger, guaranteeing a healthy life / wellbeing and provide clean water and sanitation) could be difficult to achieve. Also, NAC rural household heads' over population and competition for the available farming resources might be the consequent as a result of the relocation of the mining affected rural households heads. The pictures in the appendix indicated a significant difference between the AC and NAC material wealth which validated the result of this finding. [28] concluded that gold mining activities had potentials for rapid loss of farm economic trees, water pollution, land degradation and problems associated with mine wastes management that will eventually devastate their material wellbeing. Segilola Gold Mining Activities had been reported by [29] to have a great effect on the land use and land cover in the areas, as land use and land cover types such as rock outcrop, shrub, forest and a little portion of built-up area had been converted into a bare land and thereby reducing the material wealth possession of the rural household heads.

Table 4. Distribution of respondents based on level of the material wellbeing of the rural household heads, n = 415

Communities	Level Materialwellbeing	Freq	%	Mean / SD	Minimum score	Maximumm score
AC (n=214)	High	6	2.8	54.08±7.759	25	71
	Low	208	97.2			
NAC (n=201)	High	200	99.5	24.74±3.123	19	40
	Low	1	0.5			

Source: Field survey (2024).

Test of Hypothesis

Table 5., reveals that significant difference (t= -49.83; at P=0.000) exists between the rural household heads' material wellbeing of AC and NAC. This implies that the material wellbeing of the rural household heads in the AC had been seriously impacted by the operations of the gold miners. This might demotivate them from living in the area and future consequence on food security, income and poverty level might be unimaginable.

Table 5. Test of significant difference in the gold mining effects on material wellbeing of affected and non-affected households

		Mean of effects on material wellbeing	Std. Deviation	T	Sig	Decision
Material wellbeing	NAC	24.76	3.11	-49.827	0.000	S
	AC	53.49	7.80			

Source: Field survey (2024).

CONCLUSION

The study depicts rural households' resident in mud houses where they prominently rely on firewood as source of cooking energy in both the AC and NAC. The exploration of gold in the communities was generally affirmed to cause land degradation, reduce land availability for farming and jeopardise agricultural productivity and income. The first-hand experience of the mining effects by the rural households in AC was reflected with near consensus agreement of the adverse social, economic and environmental effects on wellbeing while

those in the NAC were mostly neutral in dispositions to the statements. As a result, the material wellbeing of the households in the AC was grossly low while their counterparts in the NAC had relatively high material wellbeing. It was concluded that gold mining activities undermined the material wellbeing of rural households resident in the mining areas. It was recommended that policy backed legislation should be put in place for the strategic relocation and adequate compensation of rural households in areas of gold exploration of Osun State, Nigeria.

REFERENCES

[1] Ericsson, M. and Lof, O. 2019. Mining's contribution to national economies between 1996 and 2016. Springer BerlinHeidelberg printing press. Retrieved June 20/ 2019 from https://doi.org/10.1007/s13563-019-00191-6.

[2] Krutilla, K., Good, D., Toman, M., Arin, T. 2021. Addressing fundamental uncertainty in benefit–cost analysis: the case of deep seabed mining. *Journal of Benefit-Cost Analysis*, *12*(1), pp.122-151

[3] World Gold Council. 2019. Gold for development. from https://www.gold.org/about-gold/gold-supply/gold-development.

[4] Wale, W. M., Tegegne, M. A. and Zeleke, M. T. 2021. Determinants of farmers' choice of land management strategies to climate change in drought prone areas of Amhara region: the case of Lay Gayint woreda, Northwest Ethiopia. *J. Degrad. Min. Lands Manag.* Vol.8, Num.2. pp.2661-2671.

[5] Saliu, A.O., Komolafe, O.O., Bamidele, C.O. and Raimi, M.O. 2023. The Value of Biodiversity to Sustainable Development in Africa. In: Izah, S.C., Ogwu, M.C. (eds) Sustainable Utilization and Conservation of Africa's Biological Resources and Environment. Sustainable Development and Biodiversity, Springer, pp.269-294.

[6] Raimi, M. O., Sawyerr, H. O., Ezekwe, I. C. and Gabriel, S. 2022. Toxicants in Water: Hydrochemical Appraisal of Toxic Metals Concentration and Seasonal Variation in Drinking Water Quality in Oil and Gas Field Area of Rivers State, Nigeria. In P. H. Saleh, and Hassan, P. A. I (Eds.), Heavy Metals - New Insights [Working Title]. IntechOpen. https://doi.org/10.5772/intechopen.102656. ISBN 978-1-80355-526-3.

[7] Omoyajowo, K. O; Raimi, M. O., Omoyajowo, K. A, Makengo, M. B, Adegboyo, S, Innocent, D. C, Oni, S., Oguntuyi, J., Oyediran, A., Ogunyebi, A. and Kakwi, D. 2024. Towards a Reduced Pollution Society: Systematic Review on the Role of Storytelling, Social Media, Humor and Celebrities'Influence for Research Communication. Journal of Appl. Sci.Environ.Manager 28(2), pp.603-623. *https://doi.org/10.4314/jasem.v28i2.34.https://www.ajol.info/index.php/ jasem/article/view/266677.*

[8] Awogbami, S. O., Solomon, O. A, Sawyerr, O. H. et al. 2022. Comparative Assessment of Seasonal Variations in the Quality of Surface water and its associated health hazards in Gold Mining Areas of Osun State, South-West Nigeria. PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-2245715/v1]. 07 November 2022.

[9] Olalekan, A. S., Adewoye, S. O., Henry, S. O., Olaniyi, O. A. and Raimi, M. O. 2023. Comprehensive understanding of hydrogeochemical evaluation of seasonal variability in groundwater quality dynamics in the gold mining areas of Osun state, Nigeria. Int J Hydro. 2023;7(5). Pp.206–220. DOI: 10.15406/ijh.2023.07.00359.

[10] Owusu, O., Bansah, K. J., & Mensah, A. K. 2019. "Small in size, but big in impact": Socio-environmental reforms for sustainable artisanal and small-scale mining. Journal of Sustainable Mining, 18(1), pp.38–44. https://doi.org/10.1016/j.heliyon.2022.e09039

[11] Adejumo, K. 2021. Illegal gold mining activities in Osun state, Nigeria: Environmental impacts and security concerns. Journal of Sustainable Development Law and Policy, 12(1), pp.45-60. https://www.ajol.info/index.php/jsdlp/article/view/261913

[12] Agboola, T.O., Akintunde, O. K., Balogun, O. L., Olorede, D.E. and Alabi, A.A. 2021: Effects of Gold Mining on Livelihood of Tree Crop Farmers in Atakumosa West Local Government Area, Osun State, Nigeria. JOFESD 7 (1): pp. 92 – 93.

[13] Ekong, E. E. 2010. Rural Sociology (3rd Edition). Dove Educational Publishers, Uyo, Akwa Ibom State, Nigeria.

[14] World Bank. 2021. Poverty Overview, World Bank, Washington DC. Retrieved from http://www.worldbank.org/en/topic/poverty/overview.99

[15] Mukaila, R., Falola, A., Akanbi, S.O., Obetta, A.E., Egwue, L.O., & Onah, T.L. 2022. Effects of vegetable production on income and livelihood of rural households in Nigeria. Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 27(2), pp.213-223.

[16] Sirgy, M. 2019. What Determines Subjective Material Well-Being?. *Social Indicators Research Series*. https://doi.org/10.1007/978-3-030-05535-6_3

[17] Omoluabi Mineral Promotion Company (OMPC). 2019. Geological and Economic Survey Results. Office of Natural and Mineral Resources. State of Osun Nigeria.

[18] Olalekan, A., Adewoye, S., Olawale, S.H., Olaniyi, O., & Raimi, M. (2022). Comprehensive Understanding of Hydrogeochemical evaluation of seasonal variability in groundwater quality Dynamics in the Gold Mining Areas of Osun State, Nigeria. https://doi.org/10.1101/2022.11.06.22282015.

[19] Awogbami, S., Solomon, O., Sawyerr, H., & Raimi, M. 2023. Comparative Assessment of Seasonal Variations in the Quality of Surface Water and Its Associated Health Hazards in Gold Mining Areas of Osun State, South-West Nigeria. Advances in Environmental and Engineering Research. https://doi.org/10.21926/aeer.2301011.

[20] Akinwumi, I., Adegoke, S., Oyelami, O., Akinwumi, A., & Adedeji, T. 2023. High blood lead levels of children in a gold mining community in Osun State, Nigeria: an urgent call for action. Transactions of the Royal Society of Tropical Medicine and Hygiene. https://doi.org/10.1093/trstmh/trad035.

[21] Adesipo, A., Akinbiola, S., Awotoye, O., Salami, A., & Freese, D. 2020. Impact of mining on the floristic association of gold mined sites in Southwest Nigeria. *BMC Ecology*, 20. Art. No9

[22] National Population Commission (NPC). 2022. National Bureau of Statistics Nigerian estimated population. *www.nbs.ng.com*

[23] Omotayo, A. O. 2020. Parametric assessment of households food intake, agriculrural practices in southwestern Nigeria. Heliyon vol. 6, Issue 11. Available at https://www.cell.com/heliyon/fulltext/S2405-8440(20)32276-3

[24] Alao, O. T., Bamiwuye, O. A and Adedokun, J. 2020. Poverty status among farming households in Ogbomoso South Local Government Area of Oyo State, Nigeria. Nigeria Journal of Rural Sociology 20 (1): pp.105 – 111.

[25] Adeniyi, R.T, and Yekinni, O.T. 2023. Livelihood information endowment as a correlate of material quality of life among rural women in Southwest, Nigeria. Journal of Agricultural Extension 27 (3): pp.1-13.
[26] Cascione, V., Maskell, D., Shea, A. and Walker, P. 2019. A review of moisture buffering capacity: From laboratory testing to full-scale measurement. Constr. Build.Material., 200 (2019), pp. pp.333-343.
[27] Timothy A. A. and Osarenmwanta, D. A. 2019. Survey of Toilet Sanitary Facilities and Water Hygiene in Rural Communities of Ovia Areas, Edo state, Nigeria. KIU Journal of Social Sciences. Kampala International University ISSN: 2413 - 9580; 5(4): pp.59 -66.
[28] Agboola, T.O., Akintunde, O. K., Balogun, O. L., Olorede, D.E. and Alabi, A.A. 2021: Effects of Gold Mining on Livelihood of Tree Crop Farmers in Atakumosa West Local Government Area, Osun State, Nigeria. JOFESD 7 (1): pp.92 – 93.
[29] Elufisan, P. (2024). Geospatial Assessment of the Effect of Gold Mining in Atakunmosa East Local Government Area, Osun State. African Journal on Land Policy and Geospatial Sciences. 7 (5). Pp. 1424-1440. DOI: https://doi.org/10.48346/IMIST.PRSM/ajlp-gs.v7i5.50385.

UTICAJI AKTIVNOSTI KOD RUDARENJA ZLATA NA MATERIJALNO BLAGOSTANJE SEOSKIH DOMAĆINSTAVA U DRŽAVI OSUN, NIGERIJA

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Abstract: Ova studija je istražila efekte aktivnosti kod rudarenja zlata na materijalno blagostanje seoskih domaćinstava u državi Osun, Nigerija. Opisane su socio-ekonomske karakteristike seoskih domaćinstava, uslovi života, njihova percepcija, a takođe i njihov nivo materijalnog blagostanja.
Za izbor 415 nosilaca seoskih domaćinstava u zajednicama pogođenim rudarstvom (ZPR) i zajednicama koje nisu pogođene rudarstvom (ZNPR) korišćen je višestepeni postupak uzorkovanja.
Podaci su analizirani korišćenjem deskriptivne statistike i nezavisnog t-testa. Utvrđen prosečan godišnji prihod domaćinstva bio je 772.320 ± 352.800 i 2.682.720 ± 780.360 u ZP i ZNPR, respektivno. Većina (78,1%) nosilaca seoskih domaćinstava u ZPR sada koristi bušotine za kućnu upotrebu zbog visokog zagađenja površinskih voda, dok polovina (52,2%) ispitanika u ZNPR i dalje koristi potok ili reku za potrebe zajednice. Nosioci seoskih domaćinstava u ZNPR snažno su se protivili tvrdnji da aktivnosti vađenja zlata poboljšavaju marketing poljoprivrednih proizvoda (1,55 ± 0,64).
Takođe, nosioci domaćinstava u ZNPR nisu se složili sa tvrdnjom da aktivnosti rudarenja zlata nude alternativne izvore prihoda (1,49 ± 0,71).

Gotovo svi nosioci domaćinstava (97,2%) u područjima sa rudarenjem zlata (zajednice pogođene rudarstvom-ZPR) imali su značajno nisko materijalno blagostanje zbog velikog uticaja aktivnosti-posledica rudarenja zlata na njih, za razliku od relativno visokog (99,5%) materijalnog blagostanja u severozapadnom delu područja-oblasti, bez uticaja rudarenja zlata (zajednice koje nisu pogođene posledicama rudarenja-ZNPR).

Zaključno, aktivnosti rudarenja zlata značajno su ugrozile materijalno blagostanje domaćinstava u predelu-oblasti gde se obavlja rudarenje.

Treba sprovesti stroge regulacione propise, zasnovane na politici, radi adekvatnog preseljenja i nadoknade nosiocima domaćinstava u oblastima sa rudarenjem zlata.

Ključne reči: *Ugrožene zajednice, neugrožene zajednice, degradacija zemljišta; percepcija; nosioci seoskih domaćinstava.*

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HYDROLOGICAL REGIME IN THE ALPINE FORESTS EXPLAINED THROUGH TREE AGES, FOG PRECIPITATION, RAINFALL AND CANOPY INTERCEPTION

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Abstract: This manuscript presents a comprehensive analysis of the eco-hydrology of an Alpine mountain forest. The data series contains monitoring aspects to find effects of the role of fog during mixed rain-fog situations and particularly in an old-grown forest with presence of lichens. This research is a contribution to eco-physiology of forests and their role in regional climate change. The water balance was evaluated of the 2 systems: old forest and young forest. Diverse environmental components were directly measured and calculated to evaluate the effects of fog in old and young forests. The parameters of evapotranspiration were applied separately using time scales and eddy covariance.

Key words*: Fog, water balance, temperate mountain, precipitation, soil, canopy interception, evaporation, throughfall, old forest, rainfall*

INTRODUCTION

Mountain regions are of essential importance for water provision with an impact extending far wider than their actual range [1-5]. However, they are also strongly affected by climate change with past and projected warming exceeding the global average [6-8]. The vegetation of mountain regions, whose distribution is driven by the change of climatic and soil conditions along elevation gradients [6-8] but also influenced complex (micro) topography [9-11], is an important, but often neglected factor in the mountain water balance. In the Alps and other high mountains, the subalpine elevation belt is mostly covered by forests dominated by conifers [12-14].

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Mountain forests have a high capacity to influence the water balance by intercepting water through the canopy and releasing it back to the atmosphere as vapor, which keeps the water cycle running. Besides, mountain forests reduce runoff and increase infiltration.

Warmer temperatures may have very distinct consequences for alpine forests, such as an increase in radial growth, which may depend on sufficient water availability to compensate for the increased evapotranspiration [15-17] Thus, moisture availability needs to be considered to predict the consequences of future climate change. Forest overuse and degradation can lead to environmental problems, such as soil erosion, landslides, rockfalls, increased water runoff or reduced water storage, the drying of springs, and biodiversity loss, and have severe impacts on livelihoods or even cause human deaths. However, there are still gaps in the understanding of water redistribution in forests and its consequences for land-use management, water policies, and the climate system.

Measurements of the water balance components are usually surrounded by uncertainties and, in hydrological approaches, widely accepted oversimplifications. In ecohydrology, the latter is overcome by separating evapotranspiration into evaporation from surfaces inside the forest and transpiration by the vegetation. While tree transpiration and soil evaporation can be measured directly through sapflow sensors and for instance canopy chambers, evaporation from canopy interception can still only be estimated indirectly or modelled. Thus, there are still major uncertainties, for example, concerning the rate of wet canopy evaporation estimated from eddy covariance measurements or as the differences between precipitation, throughfall and stemflow, or those using the conventional Penman-Monteith-equation by a factor of two or more.

The aim of this study was to estimate, for the first time, the annual water balance and all of its components of a subalpine forest in South Tyrol (Central Italian Alps). Thereby we especially aimed to better understand the potential influence of fog and tree age and the associated abundance of lichens on the water balance. To estimate the water balance, we measured the relative contribution of the water components in the balance at the catchment level.

MATERIAL AND METHODS

The experiment was conducted at the Renon site, South Tyrol, in the Italian Alps (1735 m a.s.l., 46°35′11″N, 11°26′00″E). The site, IT-Ren, provides data for several monitoring networks, including Fluxnet, ICOS (https://www.icos-cp.eu/), and Lter (https://www.lter-europe.net/). The catchment has an area of 0.44 km^2. The water basin was measured on the local digital elevation model using ArcGIS software (ESRI, Redlands, CA, USA). The tree layer (diameter at breast height (DBH) >5 cm) consisted of 85% spruce [*Picea abies (L) Karst.*], 12% Swiss stone pine *(Pinus cembra L.)*, and 3% European larch (*Larix europea L.*) trees. Scots pine (*Pinus sylvestris L.*) and European rowan (*Sorbus aucuparia*) individuals were also present sparsely. The dominant tree height was approximately 29 m. The understory consisted mainly of alpenrose (*Rhododendron ferrugineum L.*) and blueberry (*Vaccinium myrtillus L.*). Intervening grasslands, which refer to the forest gaps covered by herbaceous specie were dominated by wavy hair-grass [*Deschampsia flexuosa (L.) Trin*].

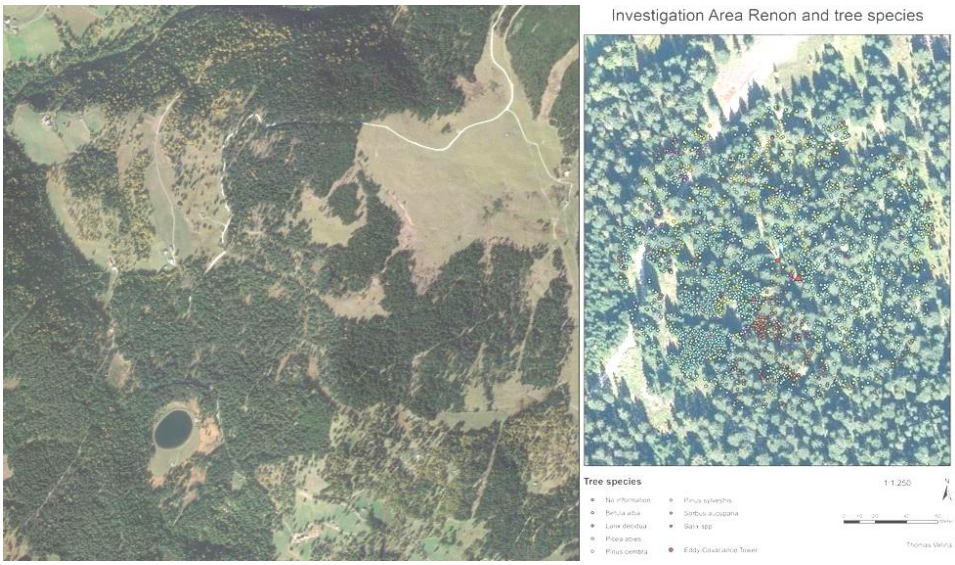

Figure 1. Study area, tree distribution and canopies from above, young and aged: UAV mounted laser estimation of canopy structure of the Renon forest site. Red triangles define the two portions of the research site selected as representative of young (blue tones) and old-growth sections (yellow tones) of the forest. In the centre of the image, the Eddy covariance tower is a red circle.

The forest is of natural origin and managed for wood production. The traditional harvest method creates small gaps, approximately 50 m wide, and involves the thinning of surrounding trees. The result is a heterogeneous vegetation structure, with groups that are almost even-aged forming an uneven-aged structure at a larger scale. A large group of dominant spruce trees with an age of approximately 200 years, and a second group of young, about 30 years-old trees were present at the study site. In both stands, parts of the living crown frequently reached the ground, irrespective of age.

The diameters and heights of the trees in the research area have been measured every ten years since 1990, while the diameter of a subset of trees is measured annually by manual dendrometers (UMS, München, Germany). The most recent inventory (tree height, size, and position) was performed in 2020 with the TruPulse sensor (TruPulse 360 B laser range-finder; Laser Tech, Centennial CO, USA). In addition, tree size was assessed during the summer of 2020 using a laser technique involving a UAV mounted laser scanner flight. Local trees and spruces were characterised by an almost columnar shape. This shape and the high leaf area index (LAI) (4.74 ± 0.88 for the 200-year-old stand and 4.65 ± 0.86 for the 30-year-old stand, as measured by hemispherical images), created peculiar microclimatic conditions within the crown, favouring lichen growth.

The soil has developed above a layer of glacial till, with a depth of approximately 1 m, placed on top of a porphyry bedrock. The soil was classified as Haplic Podzol according to the FAO soil taxonomy and on average consisted of 49% sand, 39% silt, and 12% clay.

Prediction of fog based on meteorological conditions was performed during days with rain, fog and mixed precipitation.

Meteorological variables measured during 2015 and 2019 were analysed to understand the meteorological conditions during dry and wet conditions, and especially during days with fog presence (visibility below 1 km). The ratio of diffuse to the total global radiation, the VPD, and relative air humidity (RH) were selected to characterize hours and days without precipitation, with fog-only, with rain-only and with mixed precipitation (fog and rain) during the first half of 2015 when half-hourly photos were available from a phenological camera directly at the site.

The relation between precipitation type and these three meteorological drivers were then used to predict the occurrence of fog and mixed precipitation during the study period 2019. These predictions were compared to fog observations from a public webcam (www.foto-webcam.eu/webcam/ritten/) located at 3 km and 300 m lower in elevation than the study site.

The periods characterized by dry conditions were compared, with fog and with rain, for 2015 and 2019, by including both the observation (obs) and the prediction (pred) periods to assess the accuracy of our predictions. The number of days characterized by dry conditions, fog, precipitation (rain or snowfall), and mixed precipitation for both years, 2015 and 2019, were calculated and discussed. Three representative time periods from late May to early July, from mid- July to early September and from mid-September to early November during 2019 were selected to study meteorological conditions (global radiation: total global radiation in the top row, diffuse global radiation in the middle, ratio of diffuse to total radiation, temperature and relative humidity) during dry, fog and precipitation periods and times with mismatches between observed and predicted fog.

Tree transpiration was estimated by measuring the sap flow of five spruce trees with a DBH ranging from 23 cm to 57 cm. The sap flow measurements of up to 10 trees going back to 2016 showed a representative behaviour of these trees for their size classes. To minimise errors due to incoming shortwave radiation, one sensor of the tissue heat balance sensor (Table 1) was installed at the north side of the trees. The measuring system provided sap flow rates integrated for the whole sapwood depth per unit trunk circumference (kg h-1 cm-1). The measured values were logged tat 10-min intervals and then scaled them to the tree level by multiplying them with stem circumference (minus the bark and phloem thickness measured during sensor installation) and integrated them to 30-min and daily sums per tree (L day-1).

When a sensor was installed for more than a year, we checked whether wound reaction and/or an accumulation of resin led to a decrease in sap flow by comparing the 95th percentile (P95) of 30-min sap flow rates for 2019 and the previous years. For the two smallest trees, we found a considerable decrease in the P95 sap flow and consequently corrected sap flow for 2019 by multiplying it with the ratio of P95. Minor data gaps caused by power outages or temporary sensor malfunction were filled by using a linear correlation of the respective tree's sap flow with eddy covariance evapotranspiration (R^2 = 0.57 to 0.66 at a 30-min resolution).

To estimate the canopy interception (I), we used the water balance at canopy level on a daily scale during periods with rainfall-only and mixed precipitation,

$$I = Pr + Pm - Tf - St \quad (1)$$

Where,

I is canopy water storage or interception (mm),

Pr is rainfall (mm),
Pm is mixed precipitation (rainfall during days with the presence of fog) (mm),
Tf is throughfall (mm) and St is stemflow (mm).

The accuracy of the equipment of the measured variables and the systematic error of I in Eq.2 are shown in Table 1. Data gaps owing to logger failure were filled by linear correlation with working gauges, as the correlations between them were high ($R^2 > 0.87$). The data for the manual gauges were missing for the last sampling interval and were added via a linear correlation with the results from the automatic gauges ($R^2 > 0.77$).

Stemflow was measured at one tree each at the old and young stand. Water running downwards around the tree trunk was collected into a funnel, and measured with a tipping bucket pluviometer (Table 1). The measured volume of stemflow was divided with the projected crown area of the trees to convert the data into mm. Missing values owing to logger failure were added via linear correlations with automatic throughfall measurements ($R^2 = 0.81$ for the old forest and 0.55 for the young forest).

Soil water content was measured continuously within the study site (Table 1) and the change of soil water content was calculated as the difference between the start and end of the measuring period and the hydrologic year, respectively. Water discharge at the catchment scale was measured using a combination of a water stage sensor and flow velocity measurements. The water stage sensor was placed at the lowest spot of the catchment, just above an artificial water basin (46°35′00″N, 11°26′02″E, 1,675 m a.s.l.) and continuously measured the height of the water table in the stream (S in cm). Discharge (DC in l s^{-1}) was calculated as

$$DC = a * S^b \quad (2)$$

Where,

a and b are empirical parameters according to the salt method, [19].

Precipitation below the canopy as throughfall was measured with sixteen manual rain gauges, arranged in two groups of eight in the two main forest formations, the 200-year-old section and the 30-year-old section. These pluviometers, with a 10-cm diameter orifice, were arranged in rows with a 5-m distance between each pluviometer and data were recorded almost on a weekly basis. Additionally, six tipping bucket pluviometers (with a Hobo data logger; Onset) arranged 5 m apart in two groups of three continuously recorded the below canopy precipitation at a 10-min resolution. To increase their collection representativeness, funnels with a diameter of 30 cm were placed above the orifice of each pluviometer

RESULTS

The average monthly precipitation, represented as a monthly sum and maximum daily sum, showed the importance of convective rainfall events in the warm summer, while the cold winters were comparatively dry (Tab. 1).

In 2019, the precipitation in the study area was generally in accordance with the 20-year average, except for a drier June and October and November, which were 1.5- and more than 3-fold, respectively, wetter than the average. These aberrations were also evident in the maximum daily precipitation.

In fact, an exceptional snowfall event starting on 8 November, causing a considerable snow break especially in the young forest, effectively ended our measuring season. Also, air temperature deviated from the 20-year average in 2019, mainly during the first half of the year: February and June were too warm and May was too cold.

Table 1. Days with dry conditions, fog and precipitation (rain- or snowfall) and mixed precipitation of fog plus rain-or snowfall for the whole observed period in 2015 and 2019 and the common period observed in both years.

	2015 all		2015 common period		2019 all		2019 common period	
period	1.1. - 30.8.2015		25.5. - 30.8.2015		25.5. - 7.11.2019		25.5. - 30.8.2019	
time	9-17		9-17		0-24		0-24	
	days	%	days	%	days	%	days	%
dry	123	50.6	40	41.2	79	47.3	46	47.4
fog	72	29.6	31	32.0	9	5.4	2	2.1
rain/snow	11	4.5	6	6.2	34	20.4	31	32.0
mixed precipitation	37	15.2	20	20.6	45	26.9	18	18.6
total	243	100	97	100	167	100	97	100

Tree transpiration was calculated by dividing sap flow by the projected crown area of the respective tree, thereby converting units from kg per tree to mm. The projected crown area was estimated from the mean crown radius measured in the four cardinal directions. The average tree transpiration of the two smaller trees (DBH 23 cm and 32 cm, respectively) was used to represent the young stand, while the average of the three larger trees (DBH 43 cm, 50 cm, and 57 cm, respectively) was used to represent the old stand. All the selected trees were dominant or codominant.

Throughfall rates relative to precipitation were higher in the young than in the old stand (Tab. 2) even though the LAI in both stands was similar. Throughfall variability was higher in the manual gauges than in the automatic ones as they covered a higher small-scale variability of PAI/LAI. A strong linear correlation ($R^2 > 0.93$) was found between throughfall, precipitation and precipitation for both stands and no clear increase in throughfall ratio with P, Tab. 2.

Only the last data point with the highest amount of throughfall and P was clearly above the linear regression line, indicating that the limits of the canopy's interception capacity were reached. The correlation between old and young stand throughfall was very high (Tab. 2).
Throughfall was not captured during days with fog-only. In subtropical cloud forests with a high frequency of fog, fog-only contributed with only 6% of throughfall. The high wind speed and humidity in the Japane Alps to measure up to 35% of the fog-only contribution in throughfall. Variations in height and air temperature could be explained by the Alpine forest's reduced contribution. This finding supports our theory that fog may very slightly affect the seasonal and annual water budget.

Table 2. Water components from 2019-5-30 (DOY 150) until 2019-11-07 (DOY 311) at canopy level based on daily data divided into dry and precipitation periods. Precipitation measured inside and outside the forest (minor amount of precipitation during "dry" period because periods were defined based on the outside climate station alone), throughfall and stemflow measured with automatic tipping gauges, storage/interception calculated as P - Tf - St.

Period	nr of days	P	ET	Throughfall	Stemflow	Interception
young forest						
dry	78	1.3 ± 1.8	350.2	2.62 ± 3.31	0.002	-1.34 ± 3.28
fog	8	0.1 ± 0.2	26.2	0.16 ± 0.00	0.000	-0.01 ± 0.16
Mixed fog+P	42	459.7±35.2	109.6	291.86 ±25.59	1.030	166.84 ±35.59
rain/snow	34	132.4 ±20.9	146.8	47.03 ± 11	0.055	85.31 ±18.97
old forest						
dry	78	1.3 ± 1.8	350.2	0.58 ± 0.19	0.004	0.69 ± 1.41
fog	8	0.1 ± 0.2	26.2	0.06 ± 0.00	0.000	0.09 ± 0.17
Mixed fog+P	42	459.7±35.2	109.6	216.49 ±11.43	0.774	242.46 ±29.11
rain/snow	34	132.4±20.9	146.8	35.67 ± 2.81	0.178	96.54 ±16.41

Table 3. Water components for 5 months from 2019-5-30 until 2019-11-07 at canopy level roughly divided into months according to sampling dates of the manual throughfall gauges.

Days with mixed precipitation	young forest	old forest
P measured (mm, see Table 2)	459.7 ± 35.2	459.7 ±35.2
Total Tf measured (mm)	291.9 ± 25.6	216.5 ±11.4
Contin. Table 3.	242.6 ± 6.7	184.1 ± 8.2
f estimated from rain only events (mm)		
Fog contribution in mixed events (mm)	70.3 ± 14.9	52.9 ± 4.7
measured Tf/P (%)	63.5	47.1
estimated rain-only Tf/P (%)	52.8	39.6
estimated fog Tf/P (%)	15.3	11.5
rain contribution to Tf (%)	83.1	84.1
fog contribution to Tf (%)	24.1	24.4

Throughfall rates were much greater on days with mixed fog and rain precipitation (Tab.3), whereas interception rates (I/P) were lower on days with rain only. This was discovered by examining throughfall rates at a daily resolution and differentiating by precipitation type. Fog was blamed for this Tf excess (Tf/P = 0.28 for the young stand and Tf/P = 0.27 for the old stands. Cloud forests have also shown a greater percentage of Tf on days with mixed precipitation. Days with mixed precipitation contributed the same amount of fog to Tf as days with mixed precipitation in the Spanish forests (23%). The amount of fog that contributed to throughfall during mixed precipitation did not differ considerably between the stands, and it was similar to the partition in the Spanish cloud forest (24.2%). Less than 1% of precipitation in both stands was attributed to stem flow, which was similarly noted in cloud forests.

DISCUSSION

In this study, we quantified the frequency of fog events in a subalpine coniferous forest in the Italian Alps and assessed the hydrological balance at basin and canopy scales by combining different measurement approaches. The difference between water input in rain and snow forms (fog not included) and water output as evapotranspiration and water discharge, plus the variation in the soil water content, was 25 mm, within the uncertainty range of the measurements. Thought fog has been not included in past water balance studies, our study revealed that fog combined with rainfall the same day, as mixed precipitation, contributed to higher throughfall, which in turn contributes to higher net precipitation (soil water recharge, in absence of runoff) and evaporative conditions inside the canopy.

Therefore, fog plays an important role in the water balance during numerous days with mixed precipitation, maintaining for several days a high relative humidity inside the dense coniferous crowns composing the forest. This helped the trees to maintain a large amount of leaf area, and the filamentous lichens to grow in the upper part of the canopy.

These two features led to a large capacity of the crown, particularly in the mature coniferous forest, to intercept liquid precipitation, release only a small amount of precipitation to the soil and eventually to runoff, sustaining local ET with an associated reduction of the sensible heat flux. However, how much fog was intercepted by the canopy remains open for further research.

According to the results, the juvenile stand had lower interception, which was determined by subtracting Tf from Sf and then subtracting total P. Interception was responsible for 64% of ET in the ancient forest and 33% in the young forest, as intercepted water eventually evaporates back into the sky.

This research complements, in a hydrological perspective, recent evidence that indicates that natural forests play a key role in dampening heat extremes above vegetated terrestrial ecosystems [15-17]. It also attributes to fog and cloudiness the role of linkage in the positive feedback between the presence of forests and cool and humid meteorological conditions.

CONCLUSION

The age, structure, and leaf type of the forest canopy all affect how much water it can absorb, but other elements like mosses and epiphytes can also have a significant impact. As a result, they maintain evapotranspiration, lower the Bowen ratio, raise air humidity, and store water within the forest. In this manner, rain and cloud forests preserve conditions of nearly zero water pressure deficit and provide minimal water stress to leaves, especially to epiphytes. In temperate mountain forests, where needles can survive for years and epiphytes grow on the boles and branches of old trees, this may also be the case.

In this study, the significance of the meteorological conditions (temperature, relative humidity, radiation, wind direction and speed, ratio of diffuse to total global radiation, and vapor pressure deficit) was compared during dry conditions (dry), fog (less than 1 km visibility), and rainfall in order to gain a better understanding of fog occurrence. By measuring and contrasting water interception, epiphyte composition, and temperature at various elevations with a nearby young canopy forest, the impact of older tree vegetation on the water balance was investigated. Using sap flow sensors, we determined the eddy covariance for transpiration and evapotranspiration. We assessed soil moisture in an old and young forest and made additional soil-level measurements. At the catchment level, water discharge was measured.

This study demonstrated a number of differences between the young and old stands in terms of ecosystem water partitioning at the catchment level during the course of the measurement period. In the young forest, there was more throughfall and transpiration. Rainfall water can return to the atmosphere more quickly by evaporation, which is a component of the water cycle, rather than via the soil or plant life.

REFERENCES

[1] Mansilha, C., Carvalho, A., Guimarães, P., & Espinha Marques, J. 2014. Water Quality Concerns Due to Forest Fires: Polycyclic Aromatic Hydrocarbons (PAH) Contamination of Groundwater from Mountain Areas. J*ournal of Toxicology and Environmental Health, Part A*, 77(14–16), pp. 806–815.

[2] Xi, Y.; Chao, X.; An, J.; Biao, C.; Ze, Q.; Yuan, F.; Ling, W.; Qi, W. 2025. The Coupling Coordination Characteristics and Graded Control Measures of Cultivated Land Quality and Economic Development in the Northern Slope Economic Belt of the Tianshan Mountains Based on Future Scenarios. *Sustainability*, Vol. 17, Issue 6, 2668. https://doi.org/10.3390/su17062668.

[3] Lemenkova, P. 2022. Geomorphology of the Beqaa Valley, Lebanon and Anti-Lebanon Mountains. *Acta Scientifica Naturalis,* 9(1), pp.1-22.

[4] Pantiga-Tapia, A.; Rosas-Acevedo, J.L.; Guzmán-Martínez, M.; Solís-Navarrete, J.A.; Bedolla-Solano, R.; Anzaldúa-Soulé, K.R. 2025. Biological Evaluation of Water Quality with the BMWP Index in a Section of the Tlapaneco River Affected by Two Rural Communities in the Guerrero Mountains, Mexico. *Environments*, Vol.12, Issue 3, 91. https://doi.org/10.3390/environments12030091.

[5] Qu Q, Zhang K, Niu J, Xiao C, Sun Y. 2025. Spatial–Temporal Differentiation of Ecosystem Service Trade-Offs and Synergies in the Taihang Mountains, China. *Land,* Vol.14, Issue 4(3):513. https://doi.org/10.3390/land14030513.

[6] Wang, Y., Geerts, B., Liu, C., Jing, X. 2025. A Convection-Permitting Regional Climate Simulation of Changes in Precipitation and Snowpack in a Warmer Climate over the Interior Western United States. *Climate*, 13, 46.

[7] Lemenkova, P. 2024. Machine Learning Methods of Satellite Image Analysis for Mapping Geologic Landforms in Niger: A Comparison of the Aïr Mountains, Niger River Basin and Djado Plateau. *Podzemni Radovi,* 1(45), pp.27-48.

[8] Lemenkova, P. 2025. Improving Bimonthly Landscape Monitoring in Morocco, North Africa, by Integrating Machine Learning with GRASS GIS. *Geomatics* 5, No.1: 5.

[9] Geddes, C. A., Brown, D. G., Fagre, D. B. 2005. Topography and Vegetation as Predictors of Snow Water Equivalent across the Alpine Treeline Ecotone at Lee Ridge, Glacier National Park, Montana, U.S.A. *Arctic, Antarctic, and Alpine Research*, *37*(2), pp.197–205.

[10] Hiemstra, C. A., Liston, G. E., & Reiners, W. A. 2002. Snow Redistribution by Wind and Interactions with Vegetation at Upper Treeline in the Medicine Bow Mountains, Wyoming, U.S.A. *Arctic, Antarctic, and Alpine Research*, 34(3), pp.262–273.

[11] Lemenkova, P. 2022. A Script-Driven Approach to Mapping Satellite-Derived Topography and Gravity Data Over the Zagros Fold-and-Thrust Belt, Iran. *Artificial Satellites*, 57(2), pp. 110-137.

[12] Wieser, G. (2010). Lessons from the timberline ecotone in the Central Tyrolean Alps: a review. *Plant Ecology & Diversity*, *5*(1), pp.127–139.

[13] Klaučo, M., Gregorová, B., Stankov, U. Marković, V., Lemenkova, P. 2013. Determination of ecological significance based on geostatistical assessment: A case study from the Slovak Natura 2000 protected area. *Central European Journal of Geosciences* 5, pp.28–42. http://dx.doi.org/10.2478/s13533-012-0120-0.

[14] Boyce, R. L., Friedland, A. J., Vostral, C. B., & Perkins, T. D. 2003. Effects of a major ice storm on the foliage of four New England conifers. *Écoscience*, *10*(3), pp.342–350.

[15] Oudin, L., Moulin, L., Bendjoudi, H., & Ribstein, P. 2010. Estimating potential evapotranspiration without continuous daily data: possible errors and impact on water balance simulations. *Hydrological Sciences Journal*, 55(2), pp.209–222.

[16] Lemenkova, P. 2022. Evapotranspiration, vapour pressure and climatic water deficit in Ethiopia mapped using GMT and TerraClimate dataset. *Journal of Water and Land Development,* 54(VII-IX), pp. 201-209.
[17] Tabari, H., Hosseinzadeh Talaee, P., Some'e, B.S. 2013. Spatial modelling of reference evapotranspiration using adjusted Blaney-Criddle equation in an arid environment. *Hydrological Sciences Journal*, *58*(2), pp. 408–420.
[18] Lemenkova, Polina.2021. Daljinski indeksi vegetacije izračunati programom SAGA GIS - Poređenje vertikalnog i prilagođenog pristupa promena zemljišta za sliku LANDSAT^{TM}. *Poljoprivredna tehnika,* vol. 46(3), pp. 49-60. doi: 10.5937/PoljTeh2103049L.
[19] T.J.Day and T.T.Day.1977. Field procedures and evaluation of a slug dilution gauging method in mountain streams. *Journal of Hydrology* (New Zealand). Vol. 16, No.2, pp. 113-133. https://www.jstor.org/stable/43944411.

HIDROLOŠKI REŽIM ŠUMA U ALPIMA PRIKAZAN KROZ STAROST DRVEĆA, PADAVINA SA MAGLOM, I KIŠAMA U KROŠNJAMA DRVEĆA

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Apstrakt: Ovaj rukopis predstavlja sveobuhvatnu analizu eko-hidrologije planinske šume u Centralnim Italijanskim Alpima (Južni Tirol). Serija podataka sadrži aspekte praćenja kako bi se pronašli efekti uloge magle tokom mešovitih situacija sa kišnom maglom, a posebno u staroj šumi gde je registrovano prisustvo lišajeva.
Ovo istraživanje je doprinos eko-fiziologiji šuma i njihovoj ulozi u regionalnim klimatskim promenama. Ocenjen je vodni bilans dva sistema: stara šuma i mlada šuma. Različite komponente životne sredine su direktno merene i izračunate da bi se procenili efekti magle u starim i mladim šumama.
Parametri evapotranspiracije primenjeni su posebno korišćenjem vremenskih skala i kovarijanse.

Ključne reči: *magla, vodni bilans, umerena planina, padavine, zemljište, krošnje drveća, isparavanje, propust, stara šuma, padavine*

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ANALIZA TERMINA I DEFINICIJA U POLJOPRIVREDNOJ TEHNICI I AGRARNIM DELATNOSTIMA

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Sažetak: U svim naučnim oblastima koristi se opšta i specifična terminologija na osnovu koje se determinišu aktivnosti, sadržaj rada, plan cilj i ishod rada, složenosti zadataka, učesnici i stepen stručnosti (kvalifikacija), kompetencije, predstavljaju osnovu za jasno korišćenje u pravnoj regulativi, naučno-stručnoj literatura i praksi.

Cilj ovog rada je upoređenje postojeće terminologije iz oblasti poljoprivredne tehnike i agrarne proizvodnje povezane za agrotehnikom, da kritička analiza prikaže pogodna obrazloženja o datim pojavama i pojmovima zbog uspešnijeg i preciznijeg stručnog sporazumevanja, sa uspostavljanjem jedinstvene nomenklature.

U istraživanjima je izabrano 23 termina (pojma) koji se najčešće koriste u agronomiji iz oblasti tehnike i za svaki pojam predložena originalna definicija, koje su sistematizovane kao predlog. Osim toga predložen je kriterijum podele i klasifikacije i pojmovnog imenovanja pet nižih nivoa radno-poslovne podele za 88 agrarnih delatnosti, [17].

Utvrđeno je da u literaturi postoji neusaglašenost termina za podelu nivoa organizacije poslovanja kao i naziva istog nivoa organizacije poslovanja. Obzirom na postojeću nesaglasnost nomenklature, neprecizne i neadekvatne primene termina, u ovom radu je predložena nova podela više agrodelatnosti na procese, operacije, radove i radnje (zadatke), zbog predloga otklanjanja nedostataka u teoriji i praksi.

Ključne reči: *Terminologija, poljoprivredna tehnika, agrotehnika, fitotehnika, zootehnika, procesna tehnika, procesi, operacije, radovi.*

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UVOD

Sredinom XX veka u statističkim istraživanjima proizvodnje i za potrebe izveštaja o promenama u proizvodnji u različitim privrednim granama (industrija, poljoprivreda, i druge) formirana je posebna nomenklatura proizvoda.
Posebna nomenklatura poljoprivrednih proizvoda za godišnje izveštaje iz poljoprivredne proizvodnje je uvedena 1959. godine i dopunjena članom 1., Uredbe br. 7a Veća Evropske ekonomske zajednice od 18. decembra 1959. godine, prema [1], pa je tako korišćena detaljnija nomenklatura za veći broj proizvoda.
Prema [2], primena Klasifikacije delatnosti, je pripremljena 1996. godine u skladu sa Evropskom klasifikacijom, utvrđena Zakonom o klasifikaciji delatnosti i registru jedinica razvrstavanja koji je donela Savezna skupština SRJ, na sednici Veća republika od 16. maja 1996. godine i sednici Veća građana od 19. juna 1996. godine.
Nomenklatura poljoprivrednih proizvoda predstavlja osnov za statističko prikazivanje poljoprivredne proizvodnje u fizičkim jedinicama mere. Ova nomenklatura poljoprivrednih proizvoda je odgovarajuća stepenu razvijenosti proizvodnje, usklađena je sa robnim nomenklaturama (spoljnotrgovinska) kao i sa međunarodnim standardima. Ovakva nomenklatura primenjivana za izveštaje poljoprivrede do 29. jula 2010. godine, od kada se primenjuje klasifikacija delatnosti sa nazivima, šiframa i opisima delatnosti prema Uredbi iz Službenog glasnika R. Srbije [3], koja je doneta na osnovu Zakona o klasifikaciji delatnosti objavljenog u Službenom glasniku Republike Srbije, [4].

Do danas nema mnogo podataka u literaturi na srpskom jeziku u kojoj je sadržano detaljno i sveobuhvatno razmatranje pojamova jedinstvenog imenovanja tehničkog agrarnog nasleđa, koji predstavlja poseban izazov za analizu i predlaganje rešenja i isključivanje problema koji nastaju usled neusaglašene terminologije.

Prema Autoru [15], pored *Homo agronomikusa*, postoje tri grupe osnovnih činilaca za uspešnu (veće, sigurnije, kvalitetnije i jeftinije) agrarnu proizvodnju:

1. Zemljište, podneblje, i njihova poboljšanja,
2. Produkciona svojstva biljaka i stoke (ishrana i oplemenjivanje), i
3. Razvoj agrarne tehnike i poboljšavanje agrotehnologije.

U ovom radu se predlaže detaljnije razmatranje termna i pojmova koji se koriste u oblasti poljoprivredne tehnike, jer to još nije potpuno razjašnjeno nekim dogovorom, a prema tome ni sistematizovano. To može dovesti do nekih problema u stručnoj, naučnoj i saznajnoj sferi, odnosno stručno-naučnom razumevanju. Zbog je potreban jedinstven i istovetan rečnik poimanja tehničke terminologije i drugih srodnih pojmova koji sadrži srpski jezik u okviru poljoprivredne struke.

Sagledana je prošlost u kojoj ne postoji u potpunosti sistematizovanje ovog problema, u pogledu podela na niže nivoe, koji ni u XXI veku nisu uredno ni zadovoljavajuće podeljeni, niti precizno opisani. Analizom i kritikom, a uz pomoć iskustva u praktičnom radu, predmet istraživanja je usmeren u svrhu preciznijeg određenja podeonih nivoa nižih od delatnosti ili tehnologija u poljoprivredi i agroprerađivačkoj industriji. Tako ova analiza treba da dovede do konačnog mogućeg ishoda, a to je:

prvo: poštovanje zvanične klasifikacije delatnosti,

drugo: podela agro-delatnosti na više nižih radnih nivoa od onih koji su obuhvaćeni zvaničnom klasifikacijom države, razume se uvažavajući potonju raspravu na ovu temu.

Cilj rada je da se na osnovu komparacije terminologije u poljoprivrednoj tehnici i agrarnoj proizvodnji - agrotehnici, jasno i precizno definišu obrazloženja o datim pojavama i pojmovima koja može biti osnova za uspostavljanje jedinstvene nomenklature.

MATERIJAL I METODE

Za istraživanja u ovom radu je obavljena analiza nomenklature proizvoda i delatnosti u Zakonima i odgovarajućim uredbama iz Službenog lista [1], Zakona o klasifikaciji delatnosti iz Službenog lista SRJ [2], [3], [6], i Zakona o klasifikaciji delatnosti iz Službenog glasnika RS, [4].
Korišćena je i naučna literatura u kojoj je između ostalog prikazana nomenklatura i kriterijumi podele organizacije poslovanja i delatnosti od Autora: Mrvaljević [21]; Radović i Furundžić [30]; Novković i Šomođi [24]; Munćan i Živković [22]; Radović M.M. [31]; Levi-Jakšić Maja, [12]; Mirić [15,16,17,18, 19]
Na osnovu istraživanih izvora iz literature [1-37]; urađena je uporedna analiza korišćene terminologije, ustanovljena saglasnot prema značenju i podeli i klasifikaciji nivoa organizacije poslovanja i formirana je preciznija definicija termina i predlog nomenklature.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Prošlost ljudskog društva

Autor Njegovan M.Z. [23], navodi: Čovek, da bi opstao i lagodnije radio i živeo, nadomešta time što produžava svoje organe (telo) i čula, tj. funkcije.
Čovek je to počeo je upotrebom grane, kamena i kasnije raznim tipovima oruđa od ovih materijala u interakciji: obradom kamena, a pomoću njega tojage, koca, koplja i konopca, čime je ustvari produžio dejistvo ruke.

Njegovan, M.Z., [23], navodi da je Agrokultura napredovala postepeno obzirom da su ljudi bili u situaciji da eksperimentišu, pre svega, u oblasti biljne, a zatim i stočarske proizvodnje.
Ovi eksperimenti omogućili su ljudima da ovladaju tehnikama korišćenja vode, obrade i nege zasada, da deluju u saglasnosti sa prirodnim zakonima i danas toliko pominjanim, ekološkim pravilima. Unapređenja su išla uglavnom u dva pravca: prvi je vezan za konstantno unapređenje bioloških uslova agrokulturne proizvodnje (semena, sadnica, plodnosti zemljišta, i tome slično) što je dalje stvaralo uslove za održivu agrokulturu; a drugi u u pravcu tehničkog napretka, odnosno, primenu tehničkih sredstava koja omogućavaju bolje korišćenje ili zamenu ljudske radne snage. Tako je, nakon pronalaska osnovnih agrokulturnih alatki, pre svega rala, veliki napredak ostvaren kada je umesto ljudi koji su vukli ralo, u obradu zemljišta uključena snaga životinja. Prosečna ljudska snaga koja je izmerena kao 75W, tada je učetvorostručena, pa čak i osmostručena, korišćenjem snage animalne vuče.

Vremenom, u predelima gde je dominirala agrokultura, dolazi do uspostavljanja velikog demografskog pritiska, pa se postepeno razvija metod kultivacije koji je u osnovi bio paljevinski način (nazivan milpa ili patsch agrokultura). Podrazumevao je kontrolisanu upotrebu vatre na konkretnim lokacijama odabranim za agrokulturnu proizvodnju.

Drveće je obarano ili sečeno, a sva preostala vegetacija spaljivana. Za to su korišćene mačete i noževi. Nakon paljenja, pepeo koji je ostajao na površini je popravljao plodnost zemljišta. Ali, period korišćenja zemljišta u ovom režimu je imao svoj limit. Ograničavao se na jednu ili samo nekoliko godina. Nakon toga se postupak ponavljao na drugom zemljištu. Treba istaći da je i u ovakvom režimu trebalo obezbediti adekvatnu organizaciju rada. Ovaj način bavljenja agrokulturom je bio široko rasprostranjen, a može se reći da je sa nekim izmenama, korišćen gotovo do današnjih dana. Negativna strana ovakvog pristupa je bilo nestajanje šuma usled sve većeg demografskog pritiska, i zbog toga promene klime. To je uslovilo velike migracije stanovništva. Sa protokom vremena, ovakav tok događaja je uticao da u agrokulturi dođe do specijalizacije i intenzifikacije proizvodnje. Tako započinje priprema za tzv, drugu agrokulturnu revoluciju. Ovaj period pripreme se vezuje za nastanak kolonijalizma u doba merkantilizma (okvirno od 1500 – 1950. godine). Zemljište koje se nekada koristilo za zajedničke potrebe, postepeno je postajalo predmet parcelisanja i privatnog korišćenja, što je u znatnijoj meri podsticalo razvoj agrokulture i njenu specijalizaciju. U nekim slučajevima, ova specijalizacija je išla sve do monokulturne proizvodnje.

Njegovan, M.Z., [23] dalje, navodi da se u *Prvoj agrikulturnoj revoluciji* prvo razvijaju proizvođači u agroprivrednim granama kao sistemima proizvodnje (nomadski i stacionarni sistem) npr. stočari (u srednjovekovnoj Srbiji tzv. planina) i ratari – zemljoradnja. Kasnije je u okviru pojedinih grana agroprivrede dolazilo do dalje podele rada: voćari, vinogradari, ratari, povrtari, i sl., zatim u okviru pojedinih grupa proizvoda, proizvođači, koštičavog voća, jagodastog voća, lekovitog bilja i tako dalje. Podela rada ide i dalje, do pojedinih proizvoda, npr. proizvodnja jabuka, grožđa, krompira, rena, goveda, ovaca, svinja, i drugih. Ona se odvijala i u smeru izdvajanja pojedinih radnih zahvata, odnosno, vrste posla kako u vezi sa agroprivrednom proizvodnjom, tako i u vezi sa ukupnom agrarnom privredom.

Njegovan, M.Z., [23], napominje da *Druga agrokulturna revolucija* uglavnom koincidira sa Industrijskom revolucijom. To je bila revolucija koja je agrokulturu pomerila preko granica proizvodnje za sopstvene potrebe. Osnovu ove revolucije je sačinjavala orijentacija na proizvodnju sve većih tržišnih viškova koji su bili namenjeni potrošnji industrijskih radnika (gradova) ili su služili kao sirovine za industrijske procese. U vezi sa tim se postavlja pitanje: čime je druga agrokulturna revolucija bila uslovljena? Može se reći da je pre svega bila uslovljena serijom inovacija, unapređenja i pronalazaka novih tehnika i teghnologija u Velikoj Britaniji, Holandiji, Danskoj i ostalim njima susednim zemljama. Ali, jednim delom je bila uslovljena i prenošenjem novih biljnih kultura u Evropu (krompir, kukuruz, pasulj, duvan, paradajz, paprika, itd.) koji su u pojedinim evropskim zemljama počele široko da se primenjuju tokom XVII, XVIII i XIX veka.

Vlade pojedinih država su podsticale drugu agrokulturnu revoluciju donoseći pravne akte kao što je to uradila npr. Velika Britanija. Ona je donela akte o pomorskoj trgovini i što je za agrokulturu takođe veoma značajno, tzv. akt o ogradama (Enclosure Act , Eng. Inclosure Act, iz 1773. godine je bio legalan način da se Engleskoj i Velsu, u XVIII veku, zajedničko zemljište oduzme i pretvori u veliki (ograđeni) privatni posed. Proces je započeo još u XVI veku i završen je do XIX veka). Time je obezbedila konsolidaciju zemljišnih površina koje su pretvorene u velike posede sa jednim ili samo sa nekoliko vlasnika.

To je predstavljalo jedan od mogućih načina za uvećanje veličine poseda. Međutim, u praksi su vlasnici svoja imanja uvećali na najmanje tri načina:

1) kupovinom prava na zemljište; 2) na osnovu donetog zakona;
3) na silu i često nasilj uz krvoproliće.

Ovaj proces ukrupnjavanja zemljišnih poseda je doveo do pojave velikog broja bezemljaša. Ostajući bez zemljišta, oni su se zapošljavali u agraru kao nadničari ili su prodavali svoju radnu snagu novonastajućim industrijama u gradovima kao naseobinama koje su sve više populaciono i ekonomski narastale.

Novi vlasnici velikih poseda su primenili postupak rotacije kultura, metode pripreme zemljišta, đubrenja, nege zasada i uvodili unapređene tehnike prikupljanja plodova. Radnu snagu je postepeno supstituisala mehanizacija a zemljište primena đubriva i agrohemikalija. Nove tehnike su značajno povećale produktivnost agrokulture. Prinosi u biljnoj proizvodnji su značajno porasli a došlo je i do stvaranja novih rasa stoke koje su bile visokoproduktivne u proizvodnji stočnih proizvoda (npr. mleka, mesa, i sl.). Dolazi i do značajnih inovacija u tehnici koja se koristila u agrokulturi tokom XIX i prve polovine XX veka, a da bi tehnika bila pristupačnija njenim korisnicima, razvijaju se nove bankarske i finansijske prakse. Sve zajedno, značajno je podržalo ovu agrarnu revoluciju. Ne treba zaboraviti ni doprinos nauke. Tako je npr. Johan Hajnrih fon Tinen (Nemačka), prvi početkom XIX veka analizirao prostorni karakter eknomske aktivnosti. Dalje, razvija se računovodstvo i ekonomika na gazdinstvima, prirodne nauke, itd.

Njegovan, M.Z., [23], navodi da se *Treća agrokulturna revolucija* poklapa sa tzv. postindustrijskim dobom ili kako ga često nazivaju, informatičkim dobom (IT revolucija). U ovoj revoluciji dolazi do izražaja razvoj zasnovan na znanju. Tokom industrijske revolucije (druge agrokulturne revolucije) agrar je zaostajao za industrijom, da bi u agrar ipak vremenom u potpunosti prodrle naučno industrijske metode rada i proizvodnje. Napredak je bio takav da se u razvijenim zemljama Sveta, agrokultura danas ubraja u sektor visokih 43 tehnologija kakve su svemirska, industrija automobila, i drugi tzv. hi-tec sektori. To je posledica napretka opštih i posebnih znanja. Njihova primena u agrokulturi i povezanim delatnostima je u značajnoj meri podržana informatičkim tehnologijama. Kao vodeće se ističu biotehnologija, bioinženjering, genetski inženjering, farmaceutika, biomedicina, i slično. U vezi sa tim, kao primer treba istaći da je treća agrokulturna revolucija omogućila razvoj genetskog inženjeringa i genetski modifikovanih organizama (GMO). Vodeća zemlja u tome je svakako USA sa oko 40% površina pod kukuruzom i gotovo 80% površina pod sojom. Evropa u tom pogledu gaji određene predrasude, a nerazvijene zemlje sveta u ovoj trci nemaju puno šansi jer im je ograničen pristup znanju, kapitalu i tehnologijama.

Autor [23], opisuje da se tokom treće agrarne revolucije, polovinom XX veka (1960-tih) događa i tzv. *Zelena revolucija* (Eng. Green Revolution). Ovaj pokušaj se dešava uglavnom u nerazvijenim dekolonizovanim zemljama – tzv. zemljama trećeg sveta, odnosno, svetske periferije. Ona je predstavljala pokušaj da se nove agrokulturne prakse što više rasprostru u svim delovima sveta. To se u širim razmerama uglavnom dešava tokom 1970-tih i 1980-tih godina. Plan je bio da se u nerazvijenim zemljama uvedu nova i produktivnija semena biljaka i poveća upotreba đubriva, kao i unapredi stočarstvo. To je trebalo da dovede do bržeg rasta agrokulturne proizvodnje, bržeg od rasta njihovog stanovništva i potreba.

Njegovan, M.Z., [23], navodi primer, kod Rimljana (delom i Evropa) u oblasti Mehanizacije agrokulture kada je u pitanju obrada zemljišta, koriste drvene ralice i plugovi sa animalnom vučom. U vrtovima su se koristile različiti ručni alati. Razni materijal i plodove su Rimljani transportovali jednom vrstom kola od drveta sa animalnom vučom.

Tamo gde je bilo moguće, odnosno gde su postojali uslovi za korišćenje vode (doline reka), Rimljani su unapređivali svoju proizvodnju uz upotrebu navodnjavanja (akvadukti). U procesu obrade žita, beleži se da su Rimljani i Gali koristili vodenice (u I veku n.e.). Najimpresivniji ostaci vodenica se nalaze na lokalitetu Barbegal, blizu grada Arl u južnoj Francuskoj. Šesnaest vodenih točkova vodenica poređenih u dva reda, napajali su se iz glavnog akvadukta u Arlu, tako što je izlaz vode iz jedne koristio kao ulaz za sledeću vodenicu u seriji. One su radile od kraja I do III veka n.e. Kapacitet im je procenjen na oko 4,5 t brašna na dan. To je bilo sasvim dovoljno da se sa hlebom obezbedi oko 12.500 stanovnika Arla u to vreme. Rimljani su poznavali korišćenje vertikalnih vodenih točkova. Na to ukazuje Vitruvije (*Vitruvius*) u svom radu: De Arhitectura, napisanom oko 25. godine p.n.e. kao i Plinije Stariji u svom radu: Naturalis Historia iz 77. godine n.e. Takođe su bile poznate i dosta raširene vodenice sa reversibilnim vodenim točkovima u rimskim rudnicima. U istočnom rimskom carstvu, Vizantiji, poznate su i vodenice-strugare na reci Moselle koje je opisao pesnik Ausonius. Postoje zapisi i o tome da su koristili i neku vrstu automatskih berača za zrele plodove. Veruje se da su oni ili možda pre njih i Kelti, koristili mehaničke žetelice koje su odsecale vrhove žita bez slame, a koje su pokretali najčešće volovi.

Prva kosačica (*vallus*) nastaje u I veku n.e. Izrađena je kao drveni sanduk sa dva zupčasta točka. Ova kosačica je nazivana i galsko-rimski kombajn (sačuvana je na jednom reljefu).

Plinije Stariji u svom delu Naturalis Historia XVIII, 296, iz 77. godine n.e. pominje postojanje ove kosačice. Kasnije, u mračnom srednjem veku ova mašina biva zaboravljena, pa se u to vreme, za ručnu žetvu koriste kose i srpovi.

Osim toga, Rimljani su koristili laki (*aratrum*) i teški plug (*carruca*) koje su pre njih pronašli Kelti. Povezano sa obradom i kvalitetom zemljišta, treba istaći da su Rimljani vodili računa o vrsti đubriva koje će primenjivati u poljoprivrednoj proizvodnji .

Rim je nasledio, odnosno, ili bolje je zapaziti prisvojio helensku civilizaciju, njene institucije i dostignuća. Svoj vrhunac Rim dostiže u zlatno doba Marka Aurelija oko 180 godina n.e., ali ubrzo posle toga, rimsko carstvo propada oko 476. godine n.e. Prema Autoru [23], od ukupno oko milion stanovnika kao procene da je Rim imao u to zlatno doba, ipak je 20.000 porodica siromašnih dobijalo besplatno žito za ishranu. To ukazuje na činjenicu da je dugotrajni mir koji je vladao u državi (*pax romana*), omogućio jednoobraznost zakona na celoj teritoriji, a time i najpovoljnije uslove za razvoj pa i demografski rast, odnosno, relativno veći stepen blagostanja i zbog uspešnog razvoja agrokulture.

Predhodno opisano u vezi sa razvojem agrokulture prema Autoru Njegovan, M.Z., [23], jeste činjenica da pod uticajem tehnološkog razvoja, u agraru dolazi do relativnog slabljenja značaja prirodnih uslova i resursa. Otuda neophodnost da se i nadalje vrši njeno permanentno tehnološko unapređenje. To nedvosmisleno ističe porast relativnog značaja tehničkog progresa koji se u proizvodnoj funkciji16 agrokulture dugo tretirao kao rezidual. Na osnovu efekata tehnološkog razvoja, permanentno je dolazilo do značajnih promena u produktivnosti, obimu ostvarene proizvodnje, kvalitetu primarnih proizvoda, njihovoj raznovrsnosti, nameni, i tsl. Međutim, ovaj razvoj prate i odgovarajući negativni efekti koji pre svega, vrše pritisak na životnu sredinu (vodna i erozija (vodna i eolska), zagađenje ili polucija, narušavanje ili ugrožavanje biodiverziteta, i sl.). Agrokultura sve vreme, pored proizvoda koji se koriste u ishrani stanovništva, zadovoljava i druge čovekove potrebe.

To je proizvodnja za potrebe medicine, farmaceutike, tekstilne industrije, industrije kože i obuće, a u novije vreme, proizvodi agrokulture se sve više koriste u energetici kao alternativni izvori energije, u građevinarstvu, i sl. Značaj agrokulture za ljudsko društvo je ogroman, pa ne iznenađuje činjenica da tehnološki i socijalni razvoj neminovno utiču na suštinu njenog razvoja. Njeno ispoljavanje se kreće od naturalne ka tržišno orijentisanoj komercijalnoj proizvodnji sa visokim nivoom dodate vrednosti.

Otuda je ipak nezaobilazno poznavati sve faze razvoja Agrokulture tokom istorije čovečanstva. To potvrđuje njen značaj ali istovremeno pokazuje da se sa protokom vremena menjao fokus i relativni ponder agrokulture u odnosu na predmet aktivnosti.

Autor Mirić, [17, 18]. napominje da čovek, storinama godina stvara radne i životne alatke i tehnička sredstva koja prilagođava potrebama (pomagala, nadomestke, produžetke i opštila). Istovremeno čovek zatim traži adekvatnu zamenu za svoje noge pronalaskom sanki i točka, (koji najmanje liče na noge) i ubrzava svoje kretanje na velike destinacije plutanjem, jahanjem, prevozom: zapregom, vešto povezanim balvanima (splav), različitim plovilima, prvim automobilima, vozom, traktorom, kamionom, avionom, raketom, dronom...

Produžetak vida nastaje i vatrom, tj. lučom, mada u tehničkom smislu dolazi tek otkrićem lupe u antičkom Rimu, da bi početkom Novog veka lupu pobedio mikroskop, naočare kao nadomestak, dvogled i teleskop (valjda se i zato kaže da je do kraja Srednjeg veka vladao mrak).

U isto vreme ljudske uši kao neke školjkaste antene kojima čovek hvata zvukove upozorenja, one su stražar u divljini i svim opasnim situacijama i prijemnik znanja od drugih ljudi-učitelja kada neke zvukove (govor) ljudi jedni drugima saopštavaju.

Čulo sluha je tek u IXX. veku dobilo produžetak sa prenosiocem zvuka: radio (Nikola Tesla), slušalica i telefona (Mihajlo Pupin), [17], a danas slušalice pametnih telefona su skoro postale novi podorgani ljudskog sluha pa i očiju.

Čulo mirisa i ukusa, pa i vida, zamenjeno je laboratorijskim i senzorskim ispitivanjem sadržaja i kvaliteta agro-sirovina i hrane. Sateliti su već postali geometri, agrometeorolozi, navigatori (i naravno deo neželjenih aktivnosti u oblasti špijuniranja nekih aktivnosti ljudi). PC racunar - kompjuter je posao obavezan alat, koristan sluga i naravno dostupna enciklopedija različitih znanja potrebnih ljudima. Populacija ljudi danas očekuje stostruku korist od upotrebe drona na njivama i drugih aktivnosti (na primer stočarstvo).

Pošto je u Čovek međuvremenu i progovorio – ovo je funkcija koja ljude definitivno izvukla iz divljaštva, jer su mnogo uspešnije širene informacije, tj. odbrambene inovacije.

Od tog vremena polako nestaje nerazgovetno mumlanje, cika, rika i ili nekih gestova ljudi, a zauzvrat sluh počinje da razaznaje "dogovore" životinja i glasove govornog jezika. Govor je značajan produžetak uma (mozga i nerava, koji upravljaju svim funkcijama), čime je stvorena osnova za burnu evoluciju.

Kod organa, počelo se od ruku (stvaralačkog čuda), što je sasvim prirodno – kamenim zanatstvom (razni tipovi strugač i sekira), zatim lukom i strelom, harpunom i udicom.

Pojmovi iz oblasti poljoprivredne tehnike

Tehnika je najznačajniji uzročnik smanjivanja potrebne radne snage u poljoprivredi (Tabela 1). Ona sadrži sva oruđa (ova reč je ušla i u agrarnu politiku, jer simbolizuje "oruđe vlasti") ili tehničko-mehanička sredstva za rad, koja imaju zadatak ili svrhu da unaprede poljoprivredu.

Autor [27], posmatra poljoprivrednu mehanizaciju preko standarda OECD kao etapu u procesu razvitka proizvodnje i zamenu živog rada mašinama, tj. korišćenje nebiološke energije u poljoprivredi, građevinarstvu, itd.

Poljoprivredna tehnika je važna pa ima svoju jedinstvenu ali opšteprihvaćenu terminologiju, (definisanje mora biti usaglašeno, Tabela 1.)

Tabela 1. Primenjena tehnika u agraru (poljoprivredi i agroindustriji) početkom XXI veka, [9].

Osnovni pojam	Kratak opis pojma (po redu značajnosti)
Poljoprivredna tehnika	Sva oruđa: mašine, mehanizacija, procesna tehnika, oprema, uređaji i znanja u proizvodnji i preradi agrarija, roboti, pametne tehnologije
Oruđa (uopšte)	Sva tehnika koja je "produženi organ ili čulo ljudi"
Agrotehnika	Celokupna tehnika i u poljoprivrednoj proizvodnji, tj. sistemi u tehnologiji poljoprivredne proizvodnje
Fitotehnika	Celokupna tehnika u proizvodnji biljaka ili u tehnologiji proizvodnje bilja (semena, žita, voća, grožđa, povrća, sadnog materijala (reznica), sadnica, (kulture tkiva)
Zootehnika	Celokupna tehnika u stočarskoj proizvodnji, odnosno u tehnologiji proizvodnje životinja (goveda, svinja, ovaca...)
Procesna tehnika	Sva oruđa ili postrojenja u preradi agrarnih sirovina i doradi semena, ploda i drugih (agrarnih) roba
Postrojenje (skup mašina)	Složeniji sistem povezanih uređaja za neki (složeniji) proces koji daje bar jedan (agroindustrijski) proizvod
Konstrukcija	Spoljni sklop objekta, sastav ili plan (skelet) građevine
Mehanizacija - poljoprivredna	Stabilna: mlinovi, silosi Mobilna: samopokretna, nošena i vučena sredstva, i to: Različite mašine, priključci, oruđa i pripadajuća oprema
Radna oprema (oruđe)	Ručna ili priručna, jednostavna stara sprava, tj. oruđe
Sprava, naprava	Jednostavno oruđe koje vrši neki (polu) prosti rad,, uređaj
Uređaj (mašina)	Naprava u postrojenju, namenjena za neku od operacija
Mašina	Oruđe koje ima svoj sopstveni pogon, troši i / ili stvara energiju da bi obavila operaciju koja ima svoj proizvod ili učinak
Instalacije	Spojni vodovi veza: električne energije, vode, signala, impulsa...
Aparat, aparatura	Mehanička celina koja ima namensku funkciju merenja, kuvanja, prženja, protoka (aparatura je skup aparata složenijeg oruđa)
Automat	Samopokretna sprava: radi u programiranim uslovima
Agregat	Sastav dva ili više uređaja za proizvodnju energije (pogon) i transformaciju energije u drugi oblik
Mehanizam	Sistem mašine (oruđa) koji transformiše ulazne sile ili kretanja u izlazne sile ili kretnje
Sklop	Sastav, spoj, struktura ili splet tehničkih elemenata
Instrument(i)	Sprave za merenje stanja i razni pribor u veterini (za lečenje i operativu stoke), kao i laboratorijski pribor
Priključak	Naprava (oruđe) koja se veša-nosi ili kači-vuče za pogonske mašine
Oprema, pribor	Zajednički opšti, pomoćni i dodatni sklopovi u tehnici
Alat	Zanatska oprema, sprave i pribor za radove, tj. opravke

Pojam nižih nivoa u delatnostima agro-proizvodnje i agro-tehnologije

U Evropi je zakonima uređena materija klasifikacije društveno-ekonomskih entiteta na sektore, oblasti, grane i (grupe) delatnosti, što je takođe predmet regulative Republike Srbije (Tabela 2).

Tabela 2. Grupe delatnosti agrara (poljoprivrede, agroprerađivačke industrije i veterine), [32].

Sektor	Oblasti	Grane	Broj grupa u delatnosti
A. Poljoprivreda i ribarstvo	Poljoprivreda, (lov) i prateće uslužne delatnosti	01.1 - Gajenje jednogodišnjih i dvogodišnjih biljaka	Sedam, od do broja: 01.11 - 01.16 + 01.19
		01.2 - Gajenje višegodišnjeg bilja	Devet, od do: 01.21 - 01.29
		01.3 - Gajenje sadnog materijala	Jedna: 01.30
		01.4 - Uzgoj životinja	Osam: 01.41-01.47 + 01.49
		01.5 - Mešovita agro-proizvod.	Jedna: 01.50
		01.6 - Uslužne delatnosti	Četiri: 01.61 - 01.64
	Ribarstvo i akvakultura	03.1 - Ribolov	Dve: 03.11 i 03.12
		03.2 - Akvakulture	Dve: 03.21 i 03.22
C. Agro-prerađivačka (agrarna industrija)	Proizvodnja prehrambenih proizvoda	10.1 - Prerada mesa	Tri, od do: 10.11 - 10.13
		10.2 - Prerada ribe, ljuskara	Jedna: 10.20
		10.3 - Prerada voća i povrća	Tri: 10.31, 10.32 i 10.39
		10.4 – Proizv. biljnih masti	Dve: 10.41 i 10.42
		10.5 - Mlekarstvo	Dve: 10.51 i 10.52
		10.6 – Mlinska i slična proizvodnja	Dve: 10.61 i 10.62
		10.7 - Pekarstvo i testenine	Tri, od do: 10.71 - 10.73
		10.8 - Prehrambena proizvodnja	Sedam: 10.81 - 10 i 10.89
		10.9 - Proizvodnja stočne hrane	Dve: 10.91 i 10.92
	Proizvodnja pića	11.0 - Proizvodnja pića	Sedam: 11.01 - 11.07
	Proizvodnja duvana	12.0 - Proizvodnja duvana	Jedna: 12.00
	Proizvodnja tekstila	13.1 - Predenje biljnih vlakana	Jedna: 13.10
		13.2 - Proizvodnja tkanina	Jedna: 13.20
		13.3 - Dovršavanje tekstila	Jedna: 13.30
		13.9 - Proizvodnja ost. tekstila	Sedam: 13.91-13.96 i 3.99
	Proizvodnja odeće	14.1 - Proizvodnja odeće	Pet: 14.11 - 14.14 + 14.19
		14.2 - Proizvodnja od krzna	Jedna: 14.20
		14.3 - Proizvodnja pletenine	Dve: 14.31 i 14.39
	Proizvodnja kože	15.1 - Štavljenje i dorada kože	Dve: 15.11 i 15.
		15.2 - Proizvodnja obuće	Jedna: 15.20
75	Veterina	75.0 Veterinarska delatnost	75.00 Veterinasrtvo

Zvanična klasifikacija najviše služi za prikupljanje statističkih podataka, kao osnove za razne analize poslovanja, ali samo do nivoa delatnosti koju poznaje Uredba o klasifikaciji delatnosti (u Tabeli 1. je preuzeta je samo klasifikacija delatnosti iz celog agrara).

Zanemarivanje Uredbe o klasifikaciji

Naučnici i univerzitetski nastavnci u Republici Srbiji dugi vremenski period zanemaruju zvaničnu klasifikaciju, iako ona postoji više od 50 godina .

Tako, Autor Jevtić [11], semenarstvu daje epitet grane, a ona to nije. Isto tako greši u svom radu [36], i Tomasović. Greška je prisutna u radu [14], Autora Mihaljeva i Mišića. Autor Pucarić i saradnici imaju sličnu grešku u radu [30]. Nisu u pravu Autori Simin i saradnici [34], koji navode u radu da je semenarstvo sistem. Semenarstvo u opštem organizaciono-naučnom pogledu treba da bude sistem, ali ni u bilo kom slučaju nije posebna grana, kako ga svrstavaju njegovi najučeniji protagonisti, već grupa delatnosti sa više nižih proizvodno-tehnoloških nivoa i zanimanja prema Autorima Mirić, [15], i Mirić i saradnici, [16].

Autor Zagožen [10], vidi dva "najznačajnija podsistema" u poljoprivredi: ratarstvo sa proizvodnjom krmnog bilja, ali i stočarstvo, gde se podsistem odnosi na dve grane poljoprivrede.

Autori Oljača, Raičević, Gligorević, [25] prikazuju "oblast radova sa zemljištem...(i) ...prateće radove". Bekrić [9], piše da "stočarstvo. počinje da se razvija u novu privrednu oblast sa krugom industrijskih grana...". Kasnije u istom tekstu ovaj Autor piše da je proizvodnja stočne hrane "delatnost", a ona nije ni oblast ni delatnost nego grana (po zvaničnoj klasifikaciji, Tabela 2. tačka 10.9).

Udžbenici (inače izvrsni) iz XXI veka nisu imuni na navedene pogreške. Autor Molnar [20], piše da je "Poljoprivredna proizvodnja kao privredna grana...(a dalje) "Biljna proizvodnja kao grana"... (ne mogu obe biti **grane**, pošto su biljne grane deo poljoprivrede, a ona je **oblast** u **sektoru** "Poljoprivreda i ribarstvo"), prema [32].

U najnovijem udžbeniku iz savremene tehnologije proizvodnje [35], Autori Stakić M. i Urošević T., vidi se mešanje značenja izraza: proces, operacija i postupak i dr., bez jasnog ranga nivoa i sistematizacije. Pravilno tumačenje greški ovih Autora je: "Tehnološke operacije su pojedine fizičke radne faze tehnološkog postupka", odakle onda sledi: "One po svojoj prirodi ili smislu organizacije proizvodnje predstavljaju relativno nezavisne, zaokružene celine" (ne navodi se od čega su nezavisne ni kako su zaokružene kao celine).

U agronomiji Srbije se ustalio izraz "agrotehničke mere" (problem *mere* kao termin) već odmah posle II.S rata, kada Autor Spasojević u radu [34], navodi, da postoje "...posredne kulturne mere".

U stručnoj literaturi (ali i u agrarnoj politici), odavno, i sve češće sreću izrazi: "mere nege, agrotehničke mere, ili mere obrade" i drugi, sve do 2022. godine.

Ogromna pojmovna nesaglašenost vidi se i u "Velikom agronomskom priručniku" [37], koji za isti nivo proizvodnje paušalno nudi razne izraze: "operacije"="proizvodnja"="vrsta posla"="vrsta rada". (Navedeni primeri reči su sporni ili su van date stvarnosti).

Podeoni nivoi niži od delatnosti kao problem klasifikacije

Sistematskom analizom agronomske i organizacijske literature uočene su česte nedoslednosti i pogrešne podele ove materije ne samo u agronomiji, jer Autori knjiga (a to su najčešće univerzitetski nastavnici i naučnici) prilično zanemaruju zvaničnu klasifikaciju, što dovodi do pojmovne neusaglašenosti. Dosadašnji pokušaji da se izvrši dodatna (detaljnija) podela delatnosti na niže radno-podeone nivoe nije bila uspešna, jer šest citiranih radova (od devet autora) sadrže vrlo neusaglašene nivoe i izraze, i to bez ikakvog obrazloženja (Tabela 3).

Tabela 3. Podeoni nivoi u poslovanju, organizaciji preduzeća i delatnosti prema raznim autorima, [9].

Nivoi	Podela[1] prema Mrvaljević [21], (1995)	Podela prema Radović, Furundžić [31], (1997)	Podela prema Novković, Šomođi [24], (2001)	Podela prema Munćan, Živković [22], (2004)	Podela prema Radović [32], (2010)	Podela prema Levi-Jakšić [12], (2010)
I	Radni proces	Postupak	Složena operacija	Proces	Postupak	Proces
II	Operacija	Operacija	Jedinična operacija	*Posao* – grupa operacija	Operacija	Operacije
III	*Elementi* operacija	*Zahvat*	Deo operacije	Operacije	*Zahvat*	*Poslovi*
IV	*Zahvati*	Pokret	Skup radnih *zahvata*	*Elementi*	Pokret	Radovi
V	Pokreti	-	Radni *zahvat*	Postupak	-	Postupci

[1]) Autor, naglašava da se ova podela odnosi na stočarstvo
Napomena: devet (9) reči u formi *italic* slova, po svom suštinskom smislu ne mogu biti u ovoj tabeli

U tabeli 3 za prvi nivo (I) tri puta je dat pojam proces i dva puta postupak, za drugi nivo (II) svi su dali reč operacija, za treći nivo (III) dva puta zahvat, tri puta operacija i jednom poslovi, za četvrti nivo (IV) reč pokret kod dva Autora i za peti nivo (V) opet termin postupak ponovljen dva puta, a pokret jednom.

Nije moguće da ista reč ***postupak*** odražava i najsloženiji i najprostiji nivo, reč ***proces*** je jedino dat za najviši nivo i to u tri od pet kolona, operacija se učvrstila na drugom nivou, izraz ***zahvat*** pominje se u trećem (2x), četvrtom (2x) i petom nivou – jednom je ponovljena, iako mu nema mesta u ovom kontekstu.

Navedena reč (termin) najčešće znači ***radni zahvat*** uređaja u njivskoj tehnologiji ili asocira na ***rvački zahvat,*** pa joj ovde nije mesto.

U poslednjem stupcu autorka na trećem nivou daje pojam poslovi, što se mora osporiti, jer Orlić (2005) pojam "posao" navodi u sintagmi "opis poslova i zadataka", kao jedinicu rada ili skup zadataka, dužnosti i odgovornosti, gde su zadaci i dužnosti zapravo aktivnosti, a odgovornosti – obaveze. Reč "elementi" po karakteru značenja takođe ne spada u istu grupu sa prvim i potonjim pojmovima, odnosno isuviše je načelan.

U svrstavanju pojmova iza podvučenih i izraza pod navodnicima, obično su istovetna značenja, što nije održivo, kao ni reč "mere", jer taj izraz ima mesto u sistemu merenja i možda u agrarnoj politici. Zato je neophodno naći primerenu zamenu, što je moguće i preciziranjem podele poslova u svim delatnostima agrara na više nivoa, kao Predlog br. 1. (Tabela 4.).

Tabela 4. Predlog podeonih nivoa u delatnostima agrobiznisa sa poželjnim nivoima školske spreme, [17].

Nivo 0	Aktivnosti u delatnostima primarne poljoprivredne proizvoidnje i tehnologijama agroindustrije (ovim nivoom rukovode master ili diplomirani stručnjaci)	Za uspešno rukovođenje ili obavljanje poslova u svakom od navedenih nivoa i potrebna stručna sprema
I	Procesi – Tehnološki ili proizvodni (ne "mere")	Fakultet (VŠS) ili VSŠ
I I	Operacije i njihovi vidovi – Tehnološke ili proizvodne (ne "mere")	VŠ, SSŠ
I I I	Ručni / umni radovi (odluke i slično) u procesu i / ili operaciji i njihovim vidovima	SSŠ, KV
I V	Ručne, slične i zanatske radnje (predradnje, pripremne, pomoćne, tekuće, naknadne i radnje održavanja tehnike (oruđa)	SSŠ, KV, osnovna škola
V	Pokreti i potezi; podnivoi: mikro pokreti i mini potezi	Može ih biti u svakom od gornjih poslovnih nivoa
-	Postupke čini niz procedura koje se uvode saglasno ISO standardizaciji	Može ih biti u svakom od gornjih poslovnih nivoa
Fakultet (VŠS); VSŠ – Visoka strukovna škola; SSŠ – Srednja stručna škola; KV – kvalifikovani radnik		

Obrazloženje predloga rešenja sa pet nivoa

Nulti nivo nam ukazuje koje su to grupe delatnosti u kojima postoje procesi, operacije i njihovi vidovi, ručni i umni radovi i ručne i zanatske radnje, [17].

I nivo: Po pravilu, u svakoj delatnosti (proizvodnji ili tehnologiji) više je raznih procesa (proizvodnih, tehnoloških) u kojima postoje neki od dole navedenih nivoa (od II do V). Proces je nivo svake poslovne celine ili usluge, koji ima svoj unutrašnji tok i podrazumeva oruđa sa kojim ili postrojenja u kojim ("zatvorenim" tehnologijama) se odvija da bi, takođe, dao neki svoj specifičan učinak (promenu) ili krajnji poluproizvod ili robu za tržište. U tom pogledu već uveliko odomaćena sintagma procesna tehnika veoma tačno označava ovaj nivo.

Isto tako, već je uveliko prihvaćena i sintagma "procesno inženjerstvo" u vezi sa "procesnom tehnikom", koje veoma pristaju ovom prvom nivou u svakoj proizvodnji ili/i tehnologiji.

Prema rečniku ISO standarda, prema Autoru Iliću, [10] vidi proces kao skup međusobno povezanih ili delujućih aktivnosti koji pretvara ulazne u izlazne elemente, jer su ulazi jednog – često izlazi drugog procesa ili još češće neke od operacija.

Procesi se uglavnom planiraju i izvode u prirodnim (njiva, pašnjak, voćnjak) i kontrolisanim uslovima agroindustrije (na primer autoklavi i drugi uređaji), uglavnom sa posebnim oruđima.

Od sada država (ako hoće i zna) preduzima "mere" agrarne politike. A "agrotehničke mere" treba zameniti rečima agrotehnički ili tehnološki procesi, operacije, radovi, radnje.;

II nivo: Po pravilu u okviru svakog procesa postoji jedna (vrlo retko) i više operacija, koje uglavnom podrazumevaju neke od vidova, budući da u operaciji "***setva***" imamo vidove - vreme, način, dubinu i gustinu, s tim što operacije mogu imati posebne uređaje, mašine ili priključke.

Više operacija čini proces, s tim što ponekad nema razlike između operacije i procesa, koji na kraju daje proizvod, mada operacije imaju dejstvo na neke od (korisnih ili bitnih) promena. U okviru operacija mogu postojati razni ručni/umni radovi i radnje (vidi nivoe III do V);

III nivo: u okviru gornjih grupa postoje razni manje-više brojni manuelni/umni radovi, koji obuhvataju sve umne (organizacija, odluka o plodoredu, o izboru oruđa...) i mehaničko-fizičke radove i rukovanje oruđima i alatima, čija sveukupnost i raznovrsnost mora da se sadrži u opisu poslova i radnih zadataka pojedninih radnih mesta;

IV nivo: čine razne ne samo ručne već i umne radnje pojedinačnih izvršilaca: predradnje (provera oruđa), pripremne (kačenje priključaka, reglaža), tekuće (kontrola rada), pomoćne (otklon kvarova), iznuđene (izazvane višom silom) i naknadne postradnje (čišćenje i zaštita radila), i

V nivo čine pokreti (kretnje, uključenje komandi) i/li potezi, i mikro-pokreti i/li mini potezi, koji su česti u okviru suptilne tehnike i pipave tehnologije u laboratrijskim, oplemenjivačkim, poput tehnike uklanjanja prašnika u cvetu (vidi Spasojević, [34]) i sličnim radnjama (na pr. rad skalpelom u veterini, davanje injekcija).

Završni ili zajednički nivo čine postupci ili bolje reći nizovi pojednačnih postupaka koji se u ISO standardizaciji zovu procedure u bilo kom od I do V nivoa. Reč postupak u ISO rečniku znači specifičan način za izvođenje neke aktivnosti. Ovaj izraz ima i značenje: postupnost, sled, čin promene, metod, radni način, rutina, modus operandi, kako postupiti...

Ovde je mesto da se vratimo našem značajnom agronomu IXX veka Đorđu Radiću koji je 1870. Godine, prema Autoru [20], objavio svoju vrlo iscrpnu knjigu "Gajenje poljskih useva" čiji sadržaj ima samo dva podeona nivoa, koji glase "Poljski rad" ("...svi nužni poslovi...") iza koga su išli ostali naslovi: oranje, drljanje itd... U udžbenicima iz sredine XX veka već imamo tri i više nivoa podela, da bi se u knjigama iz XXI. stoleća našlo pet vertikalnih nivoa ili radno-podeonih niša. Ako se sledi uvid u treću kolonu iz Tabele. 3 onda je određeno šta treba da sadrže budući udžbenici za visoko, a šta za srednješkolsko obrazovanje.

Tabela br. 5., predstavlja primere primene proizvodnih nivoa u delatnostima gajenja žita, povrća, voća, zatim uzgoja stoke, potom u preradi pet agrosirovina i najzad u doradi semena.

Tabela 5. Primer podela poslova u više delatnosti : procesi, operacije, radovi i radnje, [17].

Delatnost u agraru*	Proizvodni procesi za	Operacije i njeni vidovi (oruđem)	Umni ili ručni radovi	Manuelne radnje (pretežno)
- Gajenje žita... - Gajenje povrća... - Gajenje voća...	- pšenicu, - kukuruz... - papriku... - paradajz... - jabuke... - kruške...	Obrada zemljišta - osnovna i - dopunska... Setva / vidovi: - gustina, dubina Sadnja /isto	Odluke - izbor radila i ručnih radova - branje... - održavanje i opravke oruđa	Predradnje Pomoćne Tekuće Iznuđene Završne Post radnje
- Gajenje svinja... - Gajenje goveda... - Gajenje ovaca...	- prasiće... - tov svinja - mleko... - telad... - meso... - vuna...	- nega podmlatka... - hranjenje... - pojenje... - muža... - striža...	Izbor oruđa - timarenje... - obrada papaka... - odvoz mleka - pranje i sl...	Predradnje Pomoćne Tekuće Iznuđene Završne Post radnje
Prerada: - mleka... - mesa... - voća... - vlakana...	- mlekarstvo - mesnu i industriju voća - tkanje...	- kuvanje... - sirenje... - sušenje... - konzerviranje... - krojenje...	- soljenje... - aditivizacija - pakovanje... - odlaganje... - peglanje...	Predradnje Pomoćne Tekuće Iznuđene Završne Post radnje
Tehnologija dorade semena	Pšenica... Kukuruz... Suncokret...	- sušenje... - selektiranje - kalibriranje	- uzorkovanje... - kontrola... - pakovanje...	Predradnje Pomoćne Tekuće Iznuđene Završne Post radnje
*Prema Uredbi o klasifikaciji delatnosti, [7].				

DISKUSIJA

Na principima prikazanih podela, potrebno je za svaku konkretnu delatnost poljoprivrednog ili agroindustrijskog preduzeća utvrditi (propisati/opisati) sve proizvodnje ili tehnologije, u njima procese i operacije, u okviru svih – radove i radnje. Potom sve poslove, zadatke i odgovornosti rasporediti: poslovodstvu da (ruko)vodi bilo proizvodnjom ili tehnologijom, odnosno procesom i operacijom, a ostalim poslenicima rasporediti radove i radnje, koji imaju odgovarajuću stručnu spremu i barataju radnim pokretima i potezima.

Ako bi ove predloge sproveli u svakoj delatnosti i preduzeću, dobija se:

A) Jedinstven podeoni međusobno uporediv sistem za pet vertikalnih nivoa poslova

B) Sedam grupa korisnih učinaka:

1. Bio bi to važan doprinos optimalnom obavljanju svih delatnosti, tj. preduzeća u agraru i olakšalo uvođenje, provođenje i poštovanje ISO standarda u celo poslovanje.

2. Značaj (ne manji) ima za kreiranje organizacije rada i sistematizacije radnih mesta, odnosno primenu studije slučaja za izmene i dopune opisa poslova i radnih zadataka, utvrđivanje i razgraničavanje odgovornosti po nosiocima, a sve u cilju ostvarivanja ekonomičnije organizacije i boljeg poslovanja preduzeća i njegovih delova.

3. Fazno ili etapno hijerarhijsko razvrstavanje poslovanja u preduzeću može pomoći merenju kvaliteta odvijanja odvojenih faza ili međufaza u celini svake proizvodnje ili tehnologije, a možda i vođenja posebnog računovodstva ili troškova.

4. Ovakve podele ili poslovno-radna grupisanja u preduzećima bitna su i za planiranje, vršenje analiza poslovnosti i produktivnosti svake radne faze u procesima, tj. za utvrđivanje normi (normiranje), hronografiju i hronometriju, utvrđivanje manjka - viška zaposlenih i nagrađivanje.

5. Iz ovako horizontalno i vertikalno podeljenih i propisanih/opisanih nivoa u svim agro-delatnostima bilo bi lakše doći do stvarne podele nastavnih programa: razdeobom onoga šta treba u školskom sistemu da znaju i uče tehničari, šta visokoškolci, šta pripada fakultetima, sve do mastera, specijalista i doktora nauka, s tim da nema prekomernog mešanja njihovih znanja i obaveza, tj. nepotrebnog preplitanja i dupliranja udžbeničkog gradiva, metodskih jedinica i lekcija po nivoima školovanja, što je do sada bilo preovladavajuće, bar u agronomiji. Ovaj pristup bi bio koristan i savetodavcima, tj. prenosiocima znanja u praksu.

6. Biće moguće, više nego do sada, ili skoro vrlo precizno, utvrđivati opise poslova svih izvršilaca i svakom zaposlenom opisati nivo i broj zadataka, odnosno sve ono što po logici spada u delokrug rukovodioca poslova i zadataka.

7. Bolje bi bilo i platno bodovanje poslova i zadataka radnih mesta, pri čemu bi od I do IV nivoa imali opadajući iznos bodova, tj. plata, budući su i nivoi škole uvek "padajući".

Na ovoj osnovi predlog je da treba koncipirati i podelu materije u udžbenicima i priručnicima. Pisci udžbenika ili nastavnih lekcija morali bi se pridržavati obaveze da opišu sve nivoe ili faze i podfaze rada, jednako procese i operacije (do sada bilo uobičajeno) kao i radove, radnje pa i neke postupke vezane za ISO standarde (koji se odnose na svakog od izvršilaca procesa), pa i važnije mikro pokrete i poteze.

Za srednje obrazovanje udžbenici treba da daju samo šemu procesa i operacije, ali uz detaljan opis radova, radnji, pokreta i poteza i, podobno tome, pisali bi se priručnici za KV radnike. Tako da -udžbenici za srednju školu ne budu skoro isti kao oni na fakultetu.

ZAKLJUČCI

Terminologija u struci ili nauci mora biti dovedena u skladan odnos sa značenjem sistematizacije stručne i naučne materije, koja se od proste-jednostavne vremenom usložnjavala i komplikovala razvojem savremene tehnike i tehnologije. Otuda proističe potreba da se srazmerno tome pravilno koristi klasifikacija sve većeg broja radnih agro-nivoa.

Pojam i reč "mere" treba ukloniti iz sfere poljoprivrednih procesa, operacija, njihovih vidova i radova u poljoprivrednoj proizvodnji i prehrambenoj industriji i ostaviti termin u sferi merenja.

U praksi i teoriji bilo koje oblasti rada neophodno je imati ili obaviti sistematiku i terminologiju materije sa različitih stanovišta radi bržeg, istovetnog i jasnog uvida u razumevanje suštine svake delatnosti ili tehnologije.

Autori stručnih, naučnih i nastavnih pismena treba da svuda uvode tačno imenovanje zvanične klasifikacije iz tabele 1. i da se pridržavaju nomenklature i opisa do kojih se dođe ovom raspravom za niže nivoe poslovanja od propisanih.

Čitaoci treba da kritikuju i predlože i obrazlože svoje viđenje u ovom radu predočenih naziva i definicija za sve niže nivoe od delatnosti, tj. u proizvodnji i tehnologiji agrara.

Kada se iz ovog radu predlozi i pojmovi usaglase treba ih ponovo objaviti kao rezultat rasprave, kako bi je mogli primenjivati u teoriji i praksi. Zato sve šeme poslovanja u bilo kojoj delatnosti (proizvodnji ili tehnologiji) treba prikazati u preduzećima ili tekstovima publicistike na niže nivoe (procese, operacije...), i na toj osnovi sačiniti organizaciju rada i sistematizaciju poslova i zadataka za svaki proizvodni proces u primarnoj poljoprivredi i svaki tehnološki proces u agroindustriji.

LITERATURA

[1] Službeni list broj 7, 30.1.1961. str. 71/612, Uredba br.7a Veće Evropske ekonomske zajednice od 18.12.1959.
[2] Službeni list SRJ, broj 31/1996, (Primena Klasifikacije delatnosti).
[3] Službeni glasnik RS, br.110-5482/2010.(Uredba: Klasifikacija delatnosti sa nazivima, šiframa i opisima delatnosti).
[4] Službeni glasnik RS, broj 104/2009. (Zakon o klasifikaciji delatnosti).
[5] Službeni list broj 7, 30.1.1961. str. 71/612. (Zakon i Uredbe o analizi nomenklature proizvoda i delatnosti).
[6] Službeni list broj SRJ., broj 31/1996, 34/1996, ispravka. (Zakon o klasifikaciji delatnosti).
[7] Službeni glasnik RS, broj 54/2010. Uredba o klasifikaciji delatnosti.
[8] Bekrić V. 1999. Industrijska proizvodnja stočne hrane. Institut za kukuruz "Zemun Polje", Beograd, str. 1-157.
[9] Zagožen F. 1987. Elementi strategije tehnološkog razvoja poljoprivrede. Hrana i razvoj, Društvo "Nikola Tesla", Beograd, str. 15-21.
[10] Ilić V. 2007. Upravljanje kvalitetom. Megatrend univerzitet. Beograd, str. 1-331.
[11] Jevtić S.. 1981. Biologija i proizvodnja semena ratarskih kultura. Nolit, str. 1-333.
[12] Levi-Jakšić Maja. 2010. Osnove operacionog menadžmenta (Menadžment tehnologije, operacija, razvoja i tehnološka strategija). FON, Beograd, ISBN 978-86-7680-135-0.
[13] Omerbegović-Bijelović Jasmina. 2016. Ugled MSP i kako meriti i poboljšati njegov kvalitet., Fakultet organizacionih nauka. XI skup privrednika i naučnika. Zbornik radova, Beograd, str. 302-316.
[14] Mihaljev I., Mišić T.1987. Semenarstvo kao faktor unapređenja proizvodnje pšenice. Uslovi i mogućnosti proizvodnje 6 miliona tona pšenice, SPITJ, str. 337-347.
[15] Mirić M. 1998. Semenarstvo kao izazov. Društvo selekcionera i semenara Srbije, Beograd, str. 1-185.
[16] Mirić M., Lekić S., Petrović R., Dražić S., Stančić I. 2004. Tehnologija proizvodnje semena. Društvo selekcionera i semenara Srbije, Beograd, str. 1-441.
[17] Mirić M. 2016. Agroevolucija.(Prošireno izdanje). Beograd, str. 1-815.
[18] Mirić M. 2019. "150 godina staleškog poljoprivrednog društva -pregled inovacija u poljoprivredi Srbije 1830-2019". Uvodni referat, Knjiga apstrakta. Teorija i praksa agrara u istorijskoj perspektivi, Urednik: Zoran Njegovan, Centar za Agrarnu istoriju – CAI, Novi Sad, str.1-65.

[19] Mirić M. 2021. Prahu oca Srpske agronomije i utemeljivaču selekcije i semenarstva. Časopis Selekcija i semenarstvo, vol.27., br.2. str. 59-64.
[20] Molnar I. 2004. Opšte ratarstvo. Poljoprivredni fakultet, Novi Sad, str. 1-478.
[21] Mrvaljević B. 1995. Stočarstvo u svetu i Jugoslaviji. Nolit, Beograd (tom 1, str. 591 i tom 2, str. 573).
[22] Munćan P., Živković D. 2004. Menadžment rada i proizvodnje u poljoprivredi. Poljoprivredni fakultet, Zemun, str. 1-437.
[23] Njegovan M. Z. 2018. Agrokultura, kratka istorija. Novi Sad, str. 1-544.
[24] Novković N., Šomođi Š. 2000. Organizacija u poljoprivredi. Poljoprivredni fakultet Novi Sad, str. 1-295.
[25] Mićo V. Oljača, Dragiša M. Raičević, Kosta B. Gligorević. 2016. Mehanizacija u melioracijama zemljišta. Udžbenik, Univerzitet u Beogradu. Drugo dopunjeno izdanje. ISBN978-86-7834-242-4., str.1-488.
[26] Oljača Mićo, Gligorević Kosta, Branković Milorad, Dimitrovski Zoran, Tanevski Dragi. 2005. Primena elektronskih komponenti na traktorima i radnim mašinama u funkciji povećanja kontrole sigurnosti i eksploatacije. Poljoprivredna tehnika. vol. 30, br.1, str.107-118.
[27] Labović V. 2005. OECD pravila za poljoprivredne i šumske traktore pred ponovnom primenom u Srbiji i Crnoj Gori. Poljoprivredne tehnika. vol.35., br.2. pp. 125-131.
[28] Labović V. 2010. Direktiva za mašine 2006/42EC, harmonizovani standardi, ocenjivanje usaglašenosti, ICE znak, Uvodno predavanje. Regionalna privredna komora Niš.
[29] Orlić R. 2005. Kadrovski menadžment. Izdavačka kuća Zoran Damnjanović i sinovi, Beograd. str.1-466.
[30] Pucarić A., Benašić P., Ćerimagić M., Čobanović M., Vidojković M. 1987. Stanje i mogućnosti proizvodnje sjemena ratarskih kultura za domaće i strano tržište. Hrana i razvoj, Jugoslovenska naučna tribina Nikola Tesla, Beograd, str. 335-344.
[31] Radović I. i Furundžić M.1997. Principi i metode organizacije i ekonomike poljoprivredne proizvodnje.Velarta, Beograd, str. 1-542.
[32] Radović M. M. 2010. Proizvodni sistemi. Fakultet organizacionih nauka, Beograd, str.1-299.
[33] Simin V., Galac S.,Turi J.1986. Tendencije u razvoju proizvodnje i dorade semena u PK Sombor, Semenarstvo, Zagreb, br.1-2.
[34] Spasojević V.1947. Oplemenjivanje biljaka (Tehnika oplemenjivanja). Poljop. Izd. preduzeće, Beograd, str. 1-100.
[35] Stakić M. i Urošević T.M.2011. Tehnološke operacije, Deo I: Mehaničke operacije. Polj. fakultet Zemun, str 1-239.
[36] Tomasović S.1984. Zasnivanje i proizvodnja osnovnog sjemena pšenice. Seminar: Proizvodnja sjemena pšenice i kukuruza, Tuheljske Toplice, Zbornik radova. str. 25-29.
[37] Grupa Autora. 1968. Veliki agronomski priručnik. Urednik Mihajlo Krstić. Izdavač Zadružna knjiga, Beograd, COBISS.CG-ID – 1551916. str. 1-932.

ANALYSIS OF TERMS AND DEFINITIONS IN AGRICULTURAL TECHNOLOGY AND AGRICULTURAL ACTIVITIES

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Summary: In all scientific fields, general and specific terms are used to define activities, work content, plan, goal and result of work, complexity of tasks, participants and degree of expertise (qualification), competences, they are the basis for a clear use in legal regulations, scientific-professional literature and practise.

The aim of the work is to compare the terminology of agricultural techniques and agricultural production in the context of agricultural techniques and to arrive at suitable explanations of the given phenomena and concepts in a critical analysis in order to enable more successful and precise professional communication and to establish a clear nomenclature.

In this research, 23 technical terms most commonly used in agronomy were selected and an original definition was proposed for each term, which was systematised as a suggestion.

In addition, the criterion of division and classification and the conceptual designation of five lower levels of division of labour and business was proposed for all agricultural activities.

It was found that there is a discrepancy in the literature between the terms used to subdivide the level of farm organisation and the designation of the same level of farm organisation. Given the existing inconsistencies in nomenclature, imprecise and inadequate application of terms, this paper proposes a new categorisation of various agricultural activities into processes, operations, works and activities (tasks) in order to suggest the elimination of deficiencies in theory and practise.

Key words: *Terminology, agricultural technique, agrotechnics, phytotechnics, zootechnics, process technology, processes, operations, works, operations*

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ASSESSMENT OF THE EFFECTIVENESS OF N- POWER PROGRAMME ON BENEFICIARIES IN IGABI LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

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Abstract: N-power is a youth empowerment scheme implemented by the Federal Government of Nigeria to address the challenges of unemployment and to alleviate poverty among youths. The study was conducted to assess the effectiveness and the challenges of N-Power programme on the beneficiaries. Two stage sampling technique was used. Four districts were selected purposively at the first stage. At the second stage, 80 n-Power beneficiaries were selected randomly at 20 per district. Data was collected with questionnaire and interview and presented with percentages, mean and frequency distribution while Chi-square was used to analysed the data.
The results showed that majority of the N- Power beneficiaries are male (58.75%), age between 27-35 years (52.50%), married (52.50%) with the household size of 2 to 5 members (65.00%) and are educated with tertiary education (67.50%).
The Chi-square result showed that X^2 statistics (30) was greater than X^2 critical (16.64) at 0.01 percent probability level, indicating that the N- Power programme was effective in improving the living conditions of the beneficiaries. N-teach, N-tech, and N-agro are the N-Power scheme available to the beneficiaries. The challenges of N-Power programme to the beneficiaries are job insecurity, delay in payments of allowance, poor monitoring, insufficient information about the programme, distance to working places and bribery and corruption.

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The study recommended proper monitoring of the programme, adequate information about the programme to the public and prompt payment of the monthly stipends to the beneficiaries.

***Key words**: Assessment, beneficiaries, N-Power, programme, youth, empowerment.*

INTRODUCTION

N-Power programme was created to help young Nigerians acquire and develop life-long skills to become active players in the domestic and global markets. It was a programme of the Federal Government of Nigeria under president Mohammadu Buhari led administration. The programme was targeted at graduates, skilled, unskilled and out-of-school youths between the ages of 18 – 35 years [8]. The programme was designed to drastically reduce Youth unemployment under the Social Investment Programme for job creation and empowerment initiatives. The focus is to provide young graduates and non-graduates with skills, tools and livelihood to enable them advance from unemployment to employment, entrepreneurship and innovation. Applications for enrolment on the programme are done online to create a level playing field for everyone and to determine which applicants' details would enable selection and direct payment through the bank accounts and Bank Verification Number (BVN) submitted. The linked programmes under N-Power will certify that each participant will learn and practice most of what is necessary to find or create work (Federal Government of Nigeria) [5].

The programme was implemented by the Federal Government of Nigeria in order to address the challenges of unemployment and to alleviate poverty among youth [9]. N-power is linked to the Federal Government's policies in the economic, employment and social development arenas. It is a government policy that is geared towards addressing social problems in education, health, agriculture, poverty and even unemployment at all levels of government i.e., Federal, State and Local Governments [9]. By introducing N-Power, the Federal Government provides a platform not only for large-scale and relevant work skills acquisition and development; but also utilizing a large volunteer workforce to fix some of the problems in public services and stimulating the larger economy.

The stipend was ₦30, 000.00 a month per beneficiary. The beneficiaries of first and second batches of the programme were about 400,000 peoples and had been concluded in all states of the federation [1]. The third batch of the programme targeted 500,000 beneficiaries all over the nation [1]. It was at the point of conclusion of the third batch this study was undertaken to assess the effectiveness of the programme on the beneficiaries in Igabi Local Government Area of Kaduna State.

The objectives of the study are to examine the demographic characteristics of the respondents, identify the types of N-Power programmes of the respondents, determine the effectiveness of N-power programme among the respondents and identify the challenges faced by the beneficiaries of the programmes.

The hypothesis of the study stated in null form that the N-power programme is not effective in improving the living conditions of the beneficiaries in the study area.

MATERIAL AND METHODS

The study was carried out in Igabi Local Government Area (ILGA) of Kaduna state. The Local Government was created out of Zaria Local Government in 1989 with its headquarters at Turunku, located in the northern part of the state with latitude of 10^0 47'N and longitude 7^0 47' E. The Local Government has thirteen districts namely: Jaji, Rigasa, Maraban Jos, Riga Chikun, Panshanu, Gwaraji, Zangoaya, Afaka, Igabi, SabonBirini, Turunku, Kerawa and Kwarau with a projected population of 581,500 as at 2016 from the 2006 national population census [7]. Igabi LG is bounded to the north by Giwa and Zaria local government areas, to the east by Soba and Kauru local government areas, to the south by Kajuru, Kaduna North, Kaduna South and Chikun local government area, and to the west Chikun and Birnin Gwari local government areas. The climate ranges from Sahel to Sudan savannah with average rainfall of 1025mm/annum, falling between May to October which last for about 4 - 5 months a year.

Two stage sampling technique was used for the study. The first stage involved purposive selection of four districts out of thirteen (13) districts in Igabi Local Government. The districts were selected based on high concentration of N- power beneficiaries. The selected districts are Afaka, Turunku, Rigachikun, and Maraban Jos. Ten (10) N-power beneficiaries were randomly selected from each district making a total of eighty (80) respondents used as sample size for the study.

Data were collected with the aid of well-structured questionnaires. The questionnaires were prepared in line with the objectives of the study and administered to the respondents by personal interview. The data collected were presented with descriptive statistics such as mean, frequency distribution, percentages and tables. The effectiveness of N-power programme on the beneficiaries was analysed and tested with Chi-square analyses.

Chi-Square (X^2) mathematical model is given as:

$$X^2 = \sum \frac{(Fo - Fe)^2}{Fe}$$

Where:
X^2 = Chi-square,
$\sum$ = Summation sign,
Fo = Observed frequencies in each cell,
Fe = Expected frequencies in each cell

RESULTS AND DISCUSSION

Demographic Characteristics of the N-Power Beneficiaries

The distribution of demographic characteristics on Table 1 showed that majority (58.75%) of the N-Power beneficiaries are male and 41.25% are female. This indicated that male benefitted more in the programme than female. Though female's beneficiaries have a fair representation. 52.50% has the highest age range of 27-35 years, followed by 38.75% with 18-26 years while 8.75% of the beneficiaries are above 35 years old.

This reveals that there was a clear violation of selection because 8.75% of the beneficiaries are above the age of 35 years contrary to the age (18 – 35 years) designed for the programme. The marital status of the beneficiaries revealed that 52.50% are married and 47.50% are single. The N-Power allowance of ₦30, 000 will provide financial support to both the married and the single beneficiaries. In term of household size, 65.00% of the beneficiaries has smaller family size of 2-5 members, the smaller family size could be as a result of the age brackets designed for the programme. 27.50% and 7.50% has household size between 6-9 and 10-13 members respectively. The educational status indicated that all categories of educational level benefitted from the programme, 67.50% of the beneficiaries have tertiary education, 18.75% has secondary education and 13.75% has Islamic education.

Table 1. Demographic distribution of the N-Power beneficiaries

Socio-Economic variables	Frequency	Percentage
Gender		
Male	47	58.75
Female	33	41.25
Age		
18-26	31	38.75
27-35	42	52.50
Above 35	7	8.75
Marital status		
Single	38	47.50
Married	42	52.50
Household size		
2-5	52	65.00
6-9	22	27.50
10-13	6	7.50
Educational qualification		
Tertiary education	54	67.50
Secondary education	15	18.75
Islamic education	11	13.75

Source: Field survey, 2019.

Types on N –Power Programme of the respondents

The types of N- Power programme of the respondents on Table 2 showed that 68.75% of the respondents are engaged in N- Teach, which constituted the largest percentage. This showed that the majority of the beneficiaries of N- Power in the study area are Teachers.

18.75% are involved in N-agro, these represents those involved in agricultural activities while the remaining 12.50% are involved in N- health, representing those involved in health care related activities. [10] in their study on contribution of N-Power programme to youth empowerment in Cross River State, Nigeria stated that the beneficiaries of N-Power programme were mostly composed of N-Teach strand of the programme, followed by N-Health strand, N-Agro and Voluntary Assets and Income Declaration Scheme (VAIDS) strands respectively.

Table 2. Distributions of the respondents according to the types of N –Power

Types of N –power	Frequency	Percentage%
N-teach	55	68.75
N-health	10	12.50
N-agro	15	18.75
Total	80	100

Source: Field survey, 2019.

Effectiveness of N-power programme among the Beneficiaries

Effectiveness is the extent to which the respondents have benefitted immensely from the N-Power Programme. The effectiveness of the programme was measured in term of the living conditions whether the N-Power Programme has improved the living conditions of the beneficiaries or not. Table 3 showed the distribution of the respondents according to the effectiveness of N-Power Programme. From the table, a larger percentage of the respondents (53.75%) claimed the N-Power programme was effective, 27.50% maintained that the programme was most effective while 12.50% and 6.25% alleged that the programme was not effective and less effective respectively. This agreed with the findings of [10] which opined that N-Power Programme contributed to empowerment of youth through poverty reduction, proficiency skills in ICT, financial empowerment, on the job experience and investment in small scale businesses. [6] stated that N-Power scheme has to a very large extent empowered the youths in Anyigba in skills acquisition, financial status, self-reliance and productivity. According to [3], the N-Power programme has had great impacts on the socio-economic livelihoods of the beneficiaries including but not limited to ease of access to basic and daily needs, providing for families, ability to enrol for further studies, etc.

Table 3. Distribution of the effectiveness of the N-power programme to the respondents

Effective	Frequency	Percentage (%)
Most Effective	22	27.50
Effective	43	53.75
Less Effective	5	6.25
Not effective	10	12.50
Total	80	100

Source: Field survey, 2019.

Chi-Square Analysis on the Effectiveness of N-Power Programme

The Chi square test of significance of the effectiveness of N-Power Programme on Table 4 showed that the calculated Chi- square value of 30 (X^2 statistics) was greater than the tabulated value of 16.64 (X^2 critical) at 0.01 percent probability level. Thus, the null hypothesis (Ho) which states that the N-power programme is not effective in improving the living conditions of the beneficiaries in the study area is hereby rejected and the alternative hypothesis (H_A) accepted. This showed that N-Power programmes are effective in the study area. This corroborates the findings of [2] which stated that significant relationship exists between N-Power programmes and poverty alleviation as well as empowerment of the youths in Rivers State.

Table 4. Chi-Square Analysis on the Effectiveness of N-Power Programme

Effectiveness of N-power	Rank	f_o	R + f_o	Total	f_e	f_e-f_o	$(f_o-f_e)^2$	$(f_o-f_e)^2/f_e$	Tabulated value@ 1%
Most effective	1	22	23	45	40	18	324	8.0	
Effective	2	43	45	88	72.22	29.22	853.81	12.0	
Less effective	3	5	8	13	11.56	6.56	43.03	4.0	
Not effective	4	10	14	24	21.33	11.33	128.37	6.0	
Total		80	90					30	16.64

Decision rule: If f- calculated is greater than f- tabulated, H_o is rejected and H_A is accepted

Challenges of N-Power Programmes to the Beneficiaries

The challenges faced by the beneficiaries of N-Power programmes as presented on Table 5 showed that there is job insecurity (25.69%) in the programme, the beneficiaries are expected to quit the job after the expiration of the programme. 19.37% and 2.77% complained of delay in payment of and unpaid allowances, and that the stipends are not paid as at when due or not paid at all, this could be due to wrong bank verification number (BVN) which accounted for 1.98%. The percentage of the beneficiaries that affirmed insufficient information and poor monitoring of the programme stood at 13.44% and 12.65% respectively. Some (11.07%) expressed unhappiness about the distance to their working places, 7.51% stated that the programme was characterized with bribery and corruption while 5.53% complained of no teacher training to most of the N-Teach beneficiaries. The results agreed with the findings of [10], [3], [4], and [2] who have embarked on similar study.

Table 5. Challenges posed by N-Power programmes to the beneficiaries

Challenges	Frequency*	Percentage
Delay in payments of allowance	49	19.37
Unpaid allowances	7	2.77
Wrong bank verification number (BVN),	5	1.98
Distance to working places	28	11.07
No training for most of N-Teach	14	5.53
Job insecurity	65	25.69
Bribery and corruption	19	7.51
Poor monitoring	32	12.65
Insufficient information	34	13.44
Total	253	100

Source: Field survey, 2019. *Multiple responses

CONCLUSIONS

The study concluded that majority of the N-Power beneficiaries are male, age between 27-35 years, married with the household size of 2-5 members and are educated with tertiary education. The programme was effective as it has improved the living conditions of the beneficiaries through financial empowerment, poverty reduction, and self-reliance by investing in small scale businesses. It can also be concluded that N-teach, N-tech, and N-agro are the N-Power scheme available to the beneficiaries.

The challenges of N-Power programme to the beneficiaries are job insecurity, delay in payments of allowance, poor monitoring, insufficient information about the programme, distance to working places and bribery and corruption. Other includes no training for most of N-Teach, unpaid allowances and wrong bank verification number.

RECOMMENDATIONS

The study recommended proper monitoring of the programme, adequate information about the programme to the public and timely payment of the monthly stipends to beneficiaries of the programme by Federal government, the unpaid allowances should be sorted out quickly and paid accordingly, the beneficiaries should be posted closer to the place of residence.

REFERENCES

[1] Abdullahi, A. T. and Furera, A. B. 2021. An Assessment of the Impact of N- Power Programme on Youth Employability and Income in Yobe State, Nigeria. *IAR Journal of Business Management*, 2 (5): pp.13- 23.

[2] Akujuru, C. A. and Enyioko, N. C. 2019. The Impact of N-Power Programmes on Poverty Alleviation in Nigeria: A Study of Rivers State, *Global Journal of Political Science and Administration, 3* (7): pp.29-50.

[3] Ayub, A. O, and Gbaa, A. G. 2020. The Impact of N-Power Programme on the Socioeconomic Livelihoods of Beneficiaries in Ibadan North Local Government Area, Oyo State, Nigeria. *International Journal of Humanities and Social Sciences*, 19 (6): pp.69-91.

[4] Dauda, A., Adeyeye M. M., Yakubu, M. M., Oni, O. O. and Umar, H. 2019. The Impact of N-Power Programme on Youth Enterprise in Minna Metropolis. *Nigeria Journal of Business Administration*, 17, (1 & 2): pp.40-52.

[5] Federal Government of Nigeria. 2018. Investing in our People: A brief of National Social Investment Programme in Nigeria.

[6] Ifatimehin, O. O., Isyak, I. O. and Omale, D. 2020. Effect of N-Power Scheme on Youth Empowerment in Anyigba, Dekina Local Government Area of Kogi State. *KIU Interdisciplinary Journal of Humanities and Social Sciences*, 1(1): pp.102-116.

[7] NPC, (2006): National Population Commission, Federal Office of Statistics. Census 2006.

[8] N- Power .2017. N-Power Information Guide: Federal Government of Nigeria, National Social Investment Programme.

[9] Obadan, M.O. 2017. *Analytical Framework for Poverty Reduction: Issues of Economic;* Ibadan: Heinemann Educational Books Limited.

[10] Odey, S. A and Sambe, N. 2019. Assessment of the Contribution of N-Power Programme to Youth Empowerment in Cross River state, Nigeria. *International Journal of Sociology and Anthropology Research, 5* (4): pp.1-13.

PROCENA EFIKASNOSTI PROGRAMA N-POWER KOD KORISNIKA U PODRUČJU LOKALNE SAMOUPRAVE IGABI DRŽAVE KADUNA, NIGERIJA

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Abstrakt: N-power je program-šema za osnaživanje mladih koju sprovodi Savezna vlada države Nigerije kako bi se suočila sa izazovima nezaposlenosti i ublažila siromaštvo među mladima.
Studija je sprovedena da se proceni efikasnost i izazovi programa N-Power na korisnike. Korišćena je dvostepena tehnika uzorkovanja. Četiri okruga su namerno odabrana u prvoj fazi istraživanja. U drugoj fazi istraživanja, 80 N-Power korisnika programa je odabrano nasumično sa 20 učesnika po okrugu. Podaci su prikupljeni upotrebom upitnika i intervjua i predstavljeni sa %, srednjim vrednostima i distribucijom učestalosti, dok je X^2 (hi-kvadrat) korišćen za statističku analizu podataka.
Rezultati su pokazali da su većina korisnika N-Power muškarci (58,75%), starosti između 27-35 godina (52,50%), oženjeni (52,50%) sa veličinom domaćinstva od 2 do 5 članova (65,00%), da su obrazovani sa visokim školskim obrazovanjem (67,50%).
Rezultat X^2 je pokazao da je vrednost X^2 (30) bila veća od kritične vrednosti X^2 (16,64) na nivou verovatnoće od 0,01 %.
Ovo ukazuje da je program N-Power bio efikasan u poboljšanju životnih uslova korisnika. N-teach, N-tech i N-agro su šeme programa N-Power, dostupne korisnicima u sprovođenju ovog istraživanja.
Izazovi N-Power programa za korisnike su nesigurnost posla, kašnjenje u isplatama naknada, loše praćenje, nedovoljna informisanost o programu, udaljenost do radnih mesta i mito i korupcija.
Studija je preporučila pravilno praćenje programa, adekvatno informisanje javnosti o programu i blagovremenu isplatu mesečnih stipendija korisnicima.

Ključne reči: *Procena, korisnici, N-Power, program, mladi, osnaživanje.*

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THE ANALYSIS OF NECK RING MECHANISM SYSTEM

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Abstract: The study and analysis of the neck ring mechanism system is an important topic in reliability. Analytical techniques become very complicated and unrealistic, especially for modern complex systems. There have been attempts in the literature to evolve more realistic techniques and failure rate and repair rate using a simulation approach for reliability analysis of systems. This work proposes a hybrid approach called Markov system dynamics (MSD), which combines the Markov approach with the system dynamics simulation approach for reliability analysis and to study the dynamic behavior of systems. This approach has the advantages of both Markov and system dynamics methodologies. The proposed framework is for a standby mechanism system that has two components one on a standby mode another one online mode with repair. The results of the simulation when compared with that obtained by traditional Markov analysis, clearly validates the MSD approach as an alternative approach for reliability analysis.

Keywords: *Simulation approach, reliability analysis, dynamic implications of standby systems, Markov system dynamics approach, complex systems.*

INTRODUCTION

Mechanism is a device which transfer motion to some desirable pattern any typically develops very low forces and transmit little power [1].
Neck Ring Mechanism is one of the most important components of an individual section machine (I.S. machine), it functions as the major component in I.S. machine and which form the neck of the bottle .it operate with high pressure of air. A neck ring mechanism for use in an I.S. glass forming machine comprising [2]:

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A rock member adapted to be supported horizontally, A pair of spaced cylinders reciprocable on rock member for movement in opposite directions, gear means coupled to said member for oscillating said member and cylinders about the longitudinal axis of said member, longitudinal grooves on the periphery of member ,a follower in each groove, each follower being supported by one of cylinders, means for adjusting at least one of followers so that the follower contacts a wall of an associated groove, and followers and grooves being arranged such that at least one pair of radically adjacent followers contact radically adjacent groove side walls of a cylinder so as to lock the cylinder on rock member whereby backlash between cylinder and rock member is eliminated [3].

In today's technological world, almost every person depends upon the continued carrying out of a broad array of compound machinery, equipment's and services for our everyday safety, security, mobility and economic welfare [4]. The concept of failure rate is vital in reliability and survival analysis. Nevertheless, obtaining the failure rate in numerous practical situations is regularly not so simple, as the structure of the system to be considered, for instance, can be rather complex or the process of the failure development cannot be explained in the simple way [6]. In these cases, an appropriate model can help a lot in deriving reliability characteristics. Time domain modeling is concerned with the behavior of system reliability over time. The simplest time-dependent failure model assumes that failures arrive randomly with inter-arrival times exponentially distributed with constant rate. Generally, researchers organize their reliability analysis via using exponential cumulative distribution function when failure rate has a constant rate [12].

The study and analysis of neck ring mechanism systems is an important topic in reliability. Analytical techniques become very complicated and unrealistic especially for modern complex systems. Traditional techniques cannot effectively deal with the uncertainties of the risk response development. Moreover, decision making process often involves the experts' subjective judgments and preferences regarding qualitative/quantitative criteria for mega projects. This problem may result in imprecise and indefinite data being present, which makes the decision-making process complex and challenging. To mitigate these difficulties,

[11] introduced a new multiple criteria decision-making approach with interval computations to conquer these difficulties for mega projects. The complexity of the modern engineering systems besides the need for realistic considerations when modeling their availability/reliability renders analytical methods very difficult to be used. Conventional neck ring mechanisms such as those disclosed in U.S.Pat. No.3.233.999 and U.S.Pat. No.3.024.571., includes a horizontal shaft which is oscillated 180° by a rack and pinion assembly. A pair of neck ring holder arms is attached to cylinders which surround the shaft and which slide telescopically along the shaft between open (apart) and closed (together) positions.

The cylinders are moved between the open and closed positions by piston assemblies which are coaxial with and integrally operable with the horizontal shaft. Both the horizontal shaft and the surrounding cylinders are splined for mutual engagement and rotation as a unit about the axis of the shaft. Neck mechanism system has attracted the attention of several authors and designers in the field of reliability theory and designer.

Controlling the Temperature of a Glass Neck Ring Mechanism

This patent was filed by [23] and assigned to Emhart Industries. This invention has focused upon controlling the temperature of a glass neck ring mechanism.

This method involves the formation of a passage in the neck ring mechanism wall, extending from external surface to a position adjacent to the cavity.

Controlling the Temperature Inflow Neck Ring Mechanism

This patent, relating to controlling the temperature of a neck ring mechanism was filed in 1984 by [23] and assigned to Emhart Industries Inc. It appears to be very close in concept to the U.S. Patent Number 4.519.827 granted to Stanley Jones the same year. In this invention an infrared, radiation transmitting device and an infrared radiation detection device are used to detect the temperature of the neck ring mechanism during the manufacture of neck ring mechanism articles. An infrared radiation transmitting device is inserted in a passage in the neck ring mechanism portion adjacent to the neck ring mechanism cavity.

Glassware neck ring mechanism machine with unitary axis

This patent was filed by Wilbur Orland Doud in 1987 and was assigned to Ball Corporation. Doud designed a glassware neck ring mechanism machine with a plunger and neck ring mechanism assembly that works in conjunction with a carriage and a parison blank neck ring mechanism. The assembly also acts to suspend the completed parison by the neck ring portion.

Glass container forming machine including neck ring mechanism cooling

This patent, relating to Glass container forming machine including neck ring mechanism cooling, was filed in 1992. by Robert S. Johnson & Robert D. Hall and was assigned to American National Can Company. It is an object of the invention to provide a simple low cost way of providing adequate cooling to a neck ring mechanism of a parison forming machine. Reduction in neck ring mechanism temperature allows increased speed of operation.

Apparatus for forming glass articles with treating mean

This patent, relating to the apparatus for forming glass articles with treating means, was filed in 1965 by John E. Cook and was assigned to Owens. The invention relates to a method and apparatus for controlling the cooling air on a Westlake glass blowing machine. In this method, a gather of glass is placed on the upper end of a spindle. When the spindle rotates, end for end, about its axis, a small amount of air is introduced to the interior of the gather to form an initial cavity.

Reliability analysis and model of neck ring mechanism

Neck ring mechanism systems have attracted the attention of several authors in the field of reliability theory. Various researchers including.

[2] has analyzed two-unit cold neck ring mechanism system models if the repair of the failed unit continues until the unit becomes as good as new.

[3] analyzed a two-unit (one priority and other ordinary) cold neck ring mechanism system model if each unit has no independent and non-identical components.

It is also assumed that, if the repair of the ordinary unit is not complete within a specified time, known as the maximum repair time, then the ordinary unit is discarded. They have assumed that failure and repair times are uncorrelated.

[4] analyzed a two-identical unit cold neck ring mechanism system model, assuming that an order is placed to replace the failed unit by a new one if the unit is not repaired during the specified time limit. Many papers in the field of reliability theory have investigated system models assuming that upon failure of a unit, it is replaced by its standby unit.

[9] presented a comparison of two models of a system that has two non-identical active series units with identical cold standbys.
[10] have studied the two-unit cold neck ring mechanism redundant system where the repairman is always available to inspect and repair the failed unit and replace the failed unit with the standby unit if it is available instantaneously. There is extensive literature on availability characteristics of neck ring mechanism systems with two or three components under varying assumptions on the failures and repairs [15,8]. Methods used in the existing literature deals with non-Markov systems involving analytical techniques such as regenerative point technique and the supplementary variables techniques which contain many differential equations. However, it is still not easy to solve these differential equations. Therefore, the issues of how to formulate and solve the system of Markov renewal equations and how to specify those undetermined functions are gradually becoming interesting and important in the analysis of stochastic models. Several research papers and books have been published that discuss various facts of reliability technology. Traditional statistical methods for recognizing and evaluating systems are not always appropriate, especially when enough data are not available. In the real world, the static mathematical models have resulted from a system full of non-deterministic nature; their parameters become non-unique uncertainties and a chain of uncertainties. There are many approaches for accounting for uncertainty and deviation, for example, mathematics models and simulation tools [7]. Many researchers have been searching for alternate methodologies for more practical and realistic reliability analysis. Simulation has been used as a powerful tool for modeling and analysis of system reliability. It is used to represent the dynamic behavior of systems in the most realistic.This work is focused on the development of a system dynamics simulation methodology for the reliability analysis of a standby system with repair. (1). The prior art neck ring mechanisms that involved a splined connection between the invert shaft and the neck ring arm elements is that the reciprocation of the arm elements relative to the invert shaft typically is primarily spring actuated, pneumatic actuation not being reliable due to air leakage in use because of the inability to properly seal a splined shaft against such leakage. (2). The Pitch line misalignment of the cylinders is a recurring problem due to backlash between the cylinders and the shaft. (3). Adjustment too tight causes increased wear which results in backlash and further misalignment of the neck molds. (4). Adjustment too loose also results in backlash. Further, the splined shaft and splined cylinders are ineffective at sealing the pneumatic piston assemblies from air leakage which may result in the neck molds not opening completely.
Interchangeable with existing mechanism and simple installation.

1. A radial ball bearing is used to ensure smooth rotation and a simplified maintenance routine
2. A shaft end seal reduces air leakage and improves operational efficiency.
3. Extremely low back-lash in the mechanism provides consistency to help improve ware quality and reduce defects.
4. A fully hardened and ground shaft with superior wear resistance qualities extends the service life and maintains accuracy throughout its life.

METHODS AND MATERIALS

Operation of the neck-ring mechanism

A neck ring mechanism for transporting, rotating and releasing a glass article which comprises, a neck ring housing, a neck ring rotatably mounted within housing and comprising a plurality of neck ring segments, an inner bearing ring mounted for rotation within housing, mean slid ably mounted, with respect to inner bearing 'ring‘ and operatively retaining neck ring segments’ for opening and closing the segments of neck ring, rotatable cam means for actuating slid ably mounted means, and means for rotating cam 'means and clamming slid ably mounted means inwardly for closing neck ring segments and for rotating neck ring.

wherein means for rotating cam means includes a main drive gear secured to cam means for unitary rotation therewith, first sprocket and gear means for rotating main drive gear and cam means in one direction for closing neck ring’ segments. Including second sprocket and gear means cooperating with first sprocket and gear means so as to rotate main drive gear in an opposite direction for opening neck ring segments. Main drive gear in an opposite direction for opening neck ring segments. Including means for limiting relative rotation between inner bearing ring and cam means to a degree sufficient for opening and closing neck ring segments. Including latch means for periodically locking inner ' bearing ring stationary with respect to housing and preventing the simultaneous rotation of inner bear ring and cam means for effecting’ the opening and closing of neck ring segments. Wherein slid ably mounted means are mounted to be rotationally fixed with respect to ‘inner bearing ring. for simultaneous rotation with the rotation of inner bearing ring and for 'remaining' rotationally stationary when inner bearing ring is locked in a Stationary position.

Modeling aims and approach

In fact, whereas the problem of determining long run availability of the system has been extensively studied in the literature, the problem of finding the reliability of the system has not satisfactorily been tackled till now. However, among several available methods, Markov method is widely used for reliability analysis. This has motivated us to propose a novel system dynamics simulation technique for reliability analysis. This technique is used to study and analyze the dynamic behavior of systems in the most realistic sense. The present work proposes a hybrid approach called as Markov system dynamic (MSD) approach which combines the Markov approach with system dynamics simulation approach to overcome some of the limitations of Markov process in a simple and efficient way for reliability analysis and to study the dynamic behavior of systems. Initially it has been proved that the stationary, continuous-time Markov models are algebraically equivalent to linear system dynamics models as shown below.

The continuous-time Markov process

A continuous-time Markov process is completely described by its transition probability function p_{ij} (t) which is the probability that the system is in state j at time t if it was in state i at time 0.

And also $p_{ij}(t + \Delta t) = p\{x(t + \Delta t) = j \mid x(0) = I\} = \sum_{k^s=1} p\{x(t + \Delta t) = j \,.\, x(t) = k \mid x(0) = i\}$

Where,
S is the total number of states that the system can occupy at any time.

Using the Baye's theorem, the above equation can be obtained according to [12] is summarized in eqn. (1).

$$pij\ (\mathrm{t}\ +\ \Delta\mathrm{t})\ = \sum_{\mathrm{k}=1}^{\mathrm{s}} P\{X\ (t+\ \Delta t) = j, X(t) = k, K(0) = i\} \times \mathrm{P}\{\mathrm{X(t)} = \mathrm{k} \mid \mathrm{X(0)} = i$$

Using the Markov's assumption of forgetfulness, the above equation can be obtained as follows:

$$pij\ (\mathrm{t}\ +\ \Delta\mathrm{t})\ = \sum_{k=1}^{S} P\{X\ (t+\ \Delta t) = j \mid X(t) = k\}\ \mathrm{P}\{\mathrm{X(t)} = \mathrm{k} \mid \mathrm{X(0)} = i$$

Defining $\lambda_{kj}(t) = P\{X\ (t+\ \Delta t) = j \mid X(t) = k\}$.
And noting that $P\{X\ (t) = k \mid X(0) = i\} = p_{ik}\ (\mathrm{t})$.

$$pij\ (\mathrm{t}\ +\ \Delta\mathrm{t})\ = \sum_{k=1}^{s} P_{ik}\ (t) \times \lambda_{kj}\ (t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

This equation is called as the Chapman–Kolmogorov equation.
$\lambda_{kj}(t)$ called the transfer rate from state k to state j at time t.
Theoretically, the transfer rates can be time varying or even state-dependent, but in general, they are assumed to be constant. This is the stationary assumption. Most of the literature on Markov process makes this stationary assumption and such models are termed as homogeneous (or stationary) Markov models.
A stationary, continuous-time Markov model is then given by [Eq. (1) becomes as follows],

$$pij\ (\mathrm{t}\ +\ \Delta\mathrm{t})\ = \sum_{k=1}^{s} P_{ik}\ (t) \times \lambda_{kj} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Transition probabilities are continuous functions of time with the following properties:

$0 \leq P_{ij} \leq 1$ for i, j and t

$\sum_{j=1}^{s} P_{ik}\ (t) = 1$ for $\mathrm{i} = 1, 2 \ldots \ldots \ldots \ldots \mathrm{S}$ ……. (3)

$\lambda_{kj}\ \geq$ for $\mathrm{k}\ \neq \mathrm{j}$

$\lambda_{kj}\ \geq$ for $\mathrm{k}\ = \mathrm{j}$

$\sum_{j=1}^{s} P_{ik}\ (t) = 0$ for $\mathrm{k} = 1, 2 \ldots \ldots \ldots \ldots \mathrm{S}$ ……..(4)

The rate of change for p(t), where p(t) is a square matrix of transition probabilities, can be written in the form of the following differential equation:

$\frac{d}{dt}\ pi(t) =\ p\ (t)R,$ ……(5)

Where R is a square matrix of the transfer rates.
It can be shown that for such a Markov process, the time spent in state I before making a transition to state j is negative exponentially distributed with mean $1/\lambda_{ij}$.

It may be noted that negative exponential distribution has the same forgetfulness as the Markovian assumption.
A system with S possible states will have S^2 differential equations which are too large a number to solve easily.

One therefore works with state probabilities.
A state probability $P_j(t)$ is defined as the probability that the system is in state j at time t (no matter in what state it was Δt time back). Thus it is the sum of the probabilities of transition from state I to j over all states ij.

$$P_{ij}(t) = \sum_{i=1}^{s} P_{ij}\ (t) \quad \text{.....(6)}$$

The instantaneous rate of change of state probabilities can be derived as,

$$\frac{d}{dt}\ pi(t) = \sum_{i=1}^{s} P_i\ (t)\ \lambda_{ij} \quad \text{.....(7)}$$

Defining P (t) as the row vector of state probabilities, these state equations can be obtained in the following vector matrix form:

$$\frac{d}{dt}\ P(t) = P\ (t)\ \times R \quad \text{.....(8)}$$

Taking transpose of both sides Eq. (8) and defining

$$\underline{Z}(t) = P^T(t),$$

And R = R^T, Eq. (8) becomes

$$\dot{\underline{Z}} = R\underline{Z}\ (t) \quad \text{..... (9)}$$

This is the familiar vector matrix state differential equation of an autonomous linear system. Thus it can be concluded that stationary, continuous-time Markov processes are representatives of autonomous linear systems.

Development of equivalent system dynamics model
In this section, a system dynamics model has been developed which is equivalent to continuous-time Markov process as described below.
Equation (7) shows that the instantaneous rate of change of *j*th state probability,

$$\frac{d}{dt}\ pj(t) = \sum_{i=1}^{s} P_i\ (t)\ \lambda_{ij} \quad \text{.....(10)}$$

This can be written as

$$\frac{d}{dt}\ P_j(t) = P_j(t)\ \lambda_{kj} + \sum_{i=1,i\neq j}^{s} P_i\ (t)\ \lambda_{ij} \quad \text{.....(11)}$$

Making use of Eq. (4), the above equation can be written as follows

$$\frac{d}{dt}\ P_j(t) = P_j(t)\left\{-\sum_{k=1,\mathrm{i}\neq\mathrm{j}}^{S} \lambda_{kj}\right\} + \sum_{i=1,\mathrm{i}\neq\mathrm{j}}^{S} P_j\ (t)\ \lambda_{kj} \quad \text{..... (12)}$$

$$\frac{d}{dt}\ P_j(t) = \sum_{i=1,i\neq j}^{s} P_i\ (t)\ \lambda_{ij} - \sum_{i=1,i\neq j}^{s} P_j\ (t)\ \lambda_{ik} \quad \text{..... (13)}$$

s

Immediately the above Eq. (13) can be recognized as a level equation with P_j as a level variable, and $\sum_{k=1,\mathrm{i}\neq\mathrm{j}}^{S} P_i\ (t)\lambda_{kj}$ as the total inflow into the level during the period $t\ and\ t\ +\ \Delta t$

$\sum_{k=1,i\neq j}^{S} P_j\,(t)\lambda_{kj}$ is the total flow out of the level.

The inflow increases the probability P_j (t) due to transitions to state j, while the outflow reduces P_j(t) due to transitions out of the state j. The transfer rates λ_{ij} and λ_{jk} are the constants associated with the input and output rates. It can be observed that rates are linearly dependent on level variables from which they emerge. Thus stationary, continuous-time Markov models are algebraically equivalent to linear system dynamics models.

A Markov system dynamic approach to system reliability/availability assessment

The procedure that we propose in this paper [16-21], develop the availability/reliability study using continuous-time system dynamics simulation is described in Table 1, where I distinguished a total of five steps.

Step 1: (System's states description). The first step of the study is the identification of the states of the system that means the selection/determination of the systems or components within the system functional or up and down states blocks, and how they relate to each other. As a result of this step, we will obtain a state transition diagram of the system that contains the relations among its components' states and their reliability features.

Step 2: (Data collection). Before starting to build the simulation model in step 3, I take note to know the design, the complete taxonomy of components of the system, and I try to find out full reliability and maintainability information of each item in terms of components' failure rate and repair date data information. I use several sources to find this information such as performance data from the actual production, expert judgments and laboratory testing.

Step 3: (Building the system dynamics simulation model). In this step, the state transition diagram of the system will be converted into equivalent MSD model. The resulting model is called as system dynamics model.

Step 4: (MSD simulation): In simulating the MSD model, an algorithm written in C was developed and it is used on a digital computer for developing various scenarios and to obtain the required simulation replications and the results.

Step 5: (Results and analysis). This step will include the presentation of result for the availability and reliability parameters corresponding to the functions of our interest in the different configurations. This step implies explaining the results obtained with the simulation, and the factors that may lead to those results, and also providing possible actions to improve system's availability or reliability to meet system's functional requirements.

Table 1. Steps in the availability/reliability assessment

Step name	Descriptions	Result
System's states description	Determination of the basic functional states for the system configuration and for the every function to analyze	List of all functional states transition diagram of the system that contains the relations among state and their reliability features
Data collection	Complication of the necessary reliability and maintenance data (and information) for each one of the considered states	Reliability and maintenance data form one state to another; failure rate, repair rate, MTTR, MTBF, MFTM, preventive schedule, time etc
Model building	Continuous-time system dynamics simulation model building	Markov system dynamics model
System dynamics simulation	Simulation scenarios and experiments design	Scenario listings, required simulation replications and the results etc.
	Simulation scenarios and experience design	Result of the parameters of availability and reliability of the functions of our interest in the different configurations
Results and analysis	Simulation results calculation	
	Simulation results calculation	interpretation of results and their discussion

Reliability assessment of a neck ring mechanism system with repair

The approach of system dynamics was created and developed in the late 1950s by a group of researchers led by Forrester at the Massachusetts Institute of Technology (MIT), Cambridge, MA [1]. It is a methodology for modeling and redesigning manufacturing, business, and similar systems that are part man, part machine [13]. It builds on information feedback theory, which provides symbols for mapping systems in terms of diagrams and equations, and a programming language for conducting computer simulations.

Another advantage of system dynamics modeling is that it is easy to experiment with alternative values of parameters.

Finally, the steady state solutions for these problems can be obtained easily by the inspection of the flow diagrams. The present work proposes MSD approach for reliability modeling of a neck ring mechanism system with repair as described in the following sections

Assumptions to analyze the system

Step 1. System's states description and assumptions

In this system, I use the following assumptions to analyze the system through Markov analysis.

The system consists of two components such that one is in online, and another is in standby mode.

The standby unit will have a reduced failure rate while in its standby mode.

Once active, the standby (backup) unit may experience the same failure rate as the online (primary) system (if they are identical units) or may have a different failure rate.

The dependency arises because the failure rate of the standby unit depends on the state of the primary unit.
Repair of the primary unit is feasible when it is in a failed state, and the system will continue to operate as long as the backup unit has not failed.
If the primary unit is restored before the backup has failed, then the system's perspective no failure has occurred, and the system returns to its initial state.
The primary unit has a failure rate λ1 and constant repair rate 'μ' whereas the standby unit is having a failure rate λ_1 when it is in online and a failure rate λ_2 when it is in standby mode.
The failure of the secondary unit while in standby remains undetected and therefore no repair is possible.
The rate diagram for Markov analysis is shown in Fig.1. In this diagram, state 1 indicates that the primary unit is in operating mode and the second (backup) unit is in standby mode, state 2 indicates that the backup unit is in operating mode and the primary unit under repair and state 4 indicates that backup unit is in the failed state. And the state 3 represents a failure (perhaps undetected) of the standby unit while in standby with λ_2 being the corresponding failure rate.
In the Markov analysis, the system reliability is established from system state probabilities which are evaluated using a rigorous mathematical treatment as discussed by several authors. However, in the proposed model, the system state probabilities are established by observing the dynamic behavior of the system over its entire simulated mission period using the system dynamics approach. This approach is as discussed in the following section.

Step 2. Data collection
The proposed MSD methodology starts after identification of the system states as mentioned in the previous section. To illustrate the above system, i consider the required data for further analysis.
I take an active component which has a failure rate (failures per day) of 0.01 and a repair rate of 0.10. An older standby component has a failure rate of 0.001 while in standby and a failure rate of 0.10 when online. Now it is required to solve for the system reliability for a planned 30-day use. This solution takes place as follows. This illustrative example is as like the system under study, i.e., a neck ring mechanism system with repair. The data regarding the constant failure and repair rates of this illustrative example have been used in the proposed MSD simulation model.

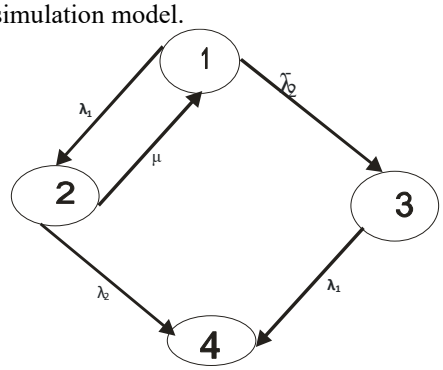

Fig.1. The Rate diagram for a standby system with repair of neck ring mechanism

Step 3. Building the system dynamics simulation model
The next step in the modeling process is to convert the rate diagram of system into the rate and level diagrams. The rate diagram (Fig.1) of the standby system with repair is now converted into a comprehensive system dynamic model. This is presented in Fig.2.
In the model depicted in Fig.2, the four states of the standby system with repair are indicated with level variables S1, S2, S3, S4 and the state transitions are indicated with rate variables (R12, R21, R13, R34, R24) with the corresponding transition rates (λ_1, λ_2, μ, λ_2)(λ_1 indicates failure rate of primary unit and μ indicates its repair rate,λ2indicates failure rate of the standby unit when it is in on line and λ_2 indicates failure rate of the standby unit when it is in standby mode).
The initial value of system reliability (as indicated at the level variable S1) is assumed as unity. The level of system reliability will be decreased by the rate of failures of either the primary unit or standby unit and it will be recovered with the repair of the primary unit before the standby unit has failed. These are measured as probability density functions (pdfs) of the system. The rate variables are influenced by the respective auxiliary variables, i.e., failure rate and repair rates of the primary unit and the failure rate of the standby unit along the entire mission or operating time. In addition, the level of failure state of the system (i.e., level variable S4) is increased by these rate variables of the primary and standby units, leading to the declining reliability of system. Figure 1 depicts the basic structure of the standby system with repair reliability model.

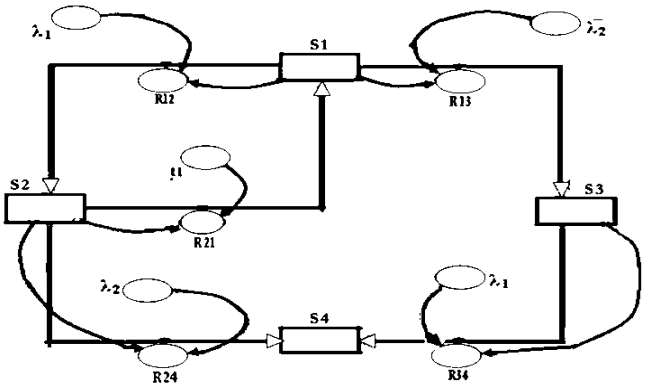

Fig. 2. A comprehensive system dynamic model of neck ring mechanism

Form figure 2 above show the comprehension system dynamic model of figure 1 above.
In the model depicted in Fig. 3.2, the four states of the standby system with repair are indicated with level variables S1, S2, S3, S4 and the state transitions are indicated with rate variables (R12, R21, R13, R34, R24) with the corresponding transition rates (λ_1, λ_2, μ, λ_2) . (λ_1 indicates failure rate of primary unit and μ indicates its repair rate, λ2 indicates failure rate of the standby unit when it is in on line and λ_2 indicates failure rate of the standby unit when it is in standby mode).

RESULTS AND DISCUSSION

The analysis of neck ring mechanism system has been completed, and the results were captured in the Figs. (3-7).

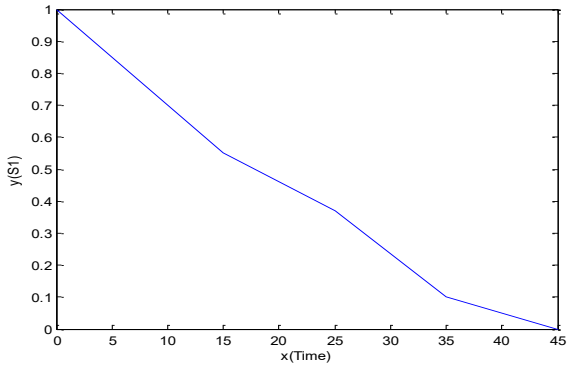

Fig.3. (S1 vs. Time) performance graph

From figure 3 above show the performance graph (state S1 vs time) its indicate that system reach its minimum level with increase in time. The system S1 decreased to it minimum level 1.0 as Time increased to the highest level of 45.

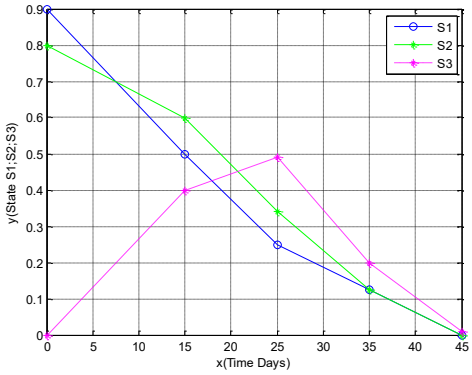

Fig.4. (State S1, S2, S3 vs. Time) performance graph

From Fig. 4 above show performance graph (state S1, S2, S3, vs time) of the system went there is increase in failure and decrease in time.
As S1 decreased to 0.9, the Time Days increased to 45. The graph of S2 decreased to 0.8 with increase in Time Days of 45. It was only S3 graph that increased to maximum of 0.5 and maintained a downward trend to 45 Time Days.

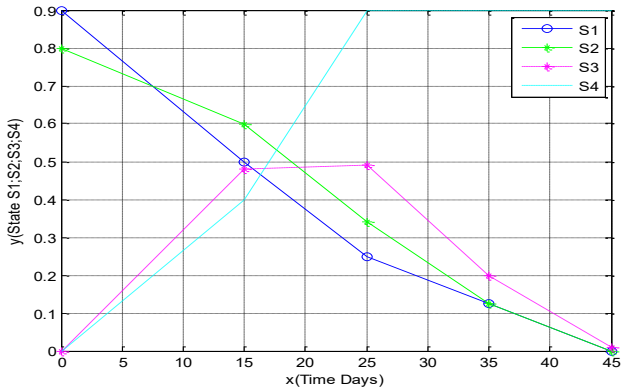

Fig.5. (State S1, S2, S3, S4, vs. Time) performance graph

From Fig. 5 above show the performance graph of the system (State S1, S2, S3, S4, vs Time) when the system simulated simultaneously by considering all its state to analyze its reliability.

It is shown in the graph of Fig.5 that the system states S1 and S2 have similar graph trend while S3 and S4 maintained a particular graph trend. The graph of system S1 decreased to 0.9, as the Time Days increased to 45. The graph of S2 decreased to 0.8 with increase in Time Days of 45. The graph of S3 increased to maximum of 0.5 at 15 to 25 Time Days and maintained a downward trend to 45 Time Days. The graph of S4 increased to 0.9 at 25 Time Days and maintained a horizontal line to 45 Time Days.

Step 4. System dynamics simulation

The next stage of MSD approach is to simulate the comprehensive MSD model of the system using the proposed algorithm. Using this, the state probabilities of the system have been calculated for reliability analysis and also the required simulation can be performed to study the dynamic behavior of the system as follow.

Proposed algorithm;

Step 1: The values of transition rates (λ_1 λ_2 μ, λ^{-}_2) and the time interval dt are taken as inputs. Also the total time T is taken as input, i.e., the time for which the system has to be simulated.

Step 2: Initially set S1 equal to one.

Step 3: Set S_i equal to zero for i =2, 3, 4.

Step 4: A conditional loop is formed with the condition, t<T.

Step 5: In each execution of the loop, the time is increased by dt, i.e., t =t + dt. So, the loop will continue till time T with each step taken at time difference dt.

Step 6: As assumed S1 initially has probability unity, and the system fails when it becomes zero. Run a conditional loop as long as the condition, i.e., the probability of S1 > 0 is satisfied.

Step 7: Within the loop all the rate variables are calculated. The probabilities of the states are calculated first and the outflow rates are calculated according to the logic as follows:

$$S1(t) = S1(t - dt) + (R21 - R12 - R13) * dt \quad \text{.....(a)}$$
$$S2(t) = S2(t - dt) + (R12 - R21 - R24) * dt \quad \text{.....(b)}$$
$$S3(t) = S3(t - dt) + (R13 - R34) * dt \quad \text{.....(c)}$$
$$S4(t) = S4(t - dt) + (R34 + R24) * dt \quad \text{.....(d)}$$

Step 8: Then all the required values are displayed and the required graphs can be drawn using these values to study the dynamic behavior.

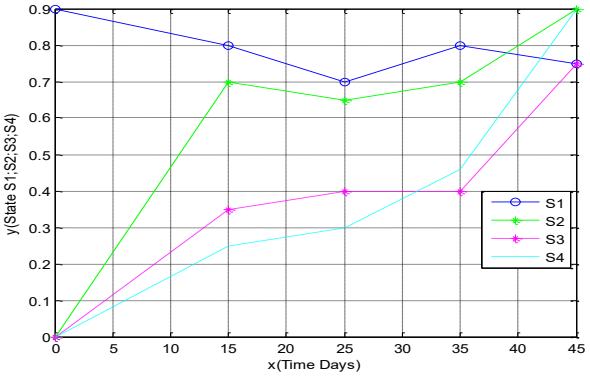

Fig. 6. Performance graph of the States against Time

From figure 6 above show performance graph at state S1, S2, S3, S4, against Time (days) as the system simulate for 45-days. The reliability of the system state S1 decreased from 0.9 with increase in Time to 45 Days. The reliability of the system state S2, S3 and S4 increased from origine to 45 Time (Days) respectively.

Table 2. The Reliability by Proposed and conventional method

Time (Days)	Reliability by Proposed model (Rs)	Reliability by Conventional method (Rc)
0	1.0	1.0
5	0.9520	0.9496
10	0.9290	0.9318
15	0.9050	0.9060
20	0.8810	0.8811
25	0.8570	0.8580
30	0.8090	0.8094

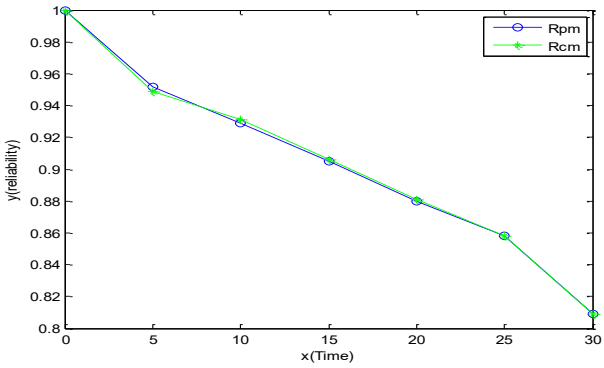

Fig.7. Comparison of results of reliability

From figure 7 above show the comparison of results: graph of reliability by proposed model (Rs) and reliability by conventional method by (Rc) from table 1.

The model experimentation

By implementing this algorithm, the model experimentation is performed as follows.
The simulation of the proposed model confirms that the operating state (reliability) of the standby system with repair decreases with increase in hazard rates as shown in Fig.3. The following experiments has been performed in this study:

Experiment 1. Test simulation run the system was first simulated with a test simulation run with an assumption that initially it is having maximum reliability, i.e., unity and the primary and standby units of the system are in operating state (i.e., at level variable S1). And the operating state of the system reaches its minimum level with increase in time.

Experiment 2. Second simulation run In a second simulation run, the system has been simulated (for 45 days) with the given values of failure rate and repair rates of the primary unit and the failure rates of the standby unit when it is in online as well as in standby mode. In this, the operating state (i.e., reliability as indicated with level variable S1) of the system reaches its minimum level with increase in time as shown in Fig.3.

Experiment 3. Third simulation run In a third run, the proposed model for the standby system with repair has been simulated (for 45 days) by considering the state 2(i.e., S2) which indicates that the backup unit is in operating mode and the primary unit under repair and also the state 3 (i.e., S3) which represents a failure (perhaps undetected) of the standby unit while in standby with λ_2^- being the corresponding failure rate as shown in Fig. 3.
Finally, the system has been simulated simultaneously by considering all of its states to analyze its reliability.
Figure 4. depicts the dynamic behavior of the standby system with repair in its all states. The simulation results in Fig.4. Clearly indicate that the operating state of the system decreases with increase in time due to primary and standby unit's failures.

And, the system will be in operating state if one of its units is in operating state (S2, S3 curves indicate this in Fig. 4.). The system reaches its failed state when both of its units fail. And the sum of S1, S2, and S3 state probabilities will give the system reliability.

RESULTS AND DISCUSSION

The results of failure rate analysis, repair analysis, replacement analysis and reliability analysis are show in Table 1 and Table 2. The failure of the component depends on the performance of the system. From the analysis show that not all the components fail due to the function of it.

From the Table 1, illustrate the replacement analysis from the analysis I observe that not all the components can be replaced.

System reliability is established from system state possibility as show in Fig.2, so to simplify this analysis, the same system has been considered.

In this work and solved using the proposed model as described earlier to calculate the reliability and the dynamic behavior of the system. The obtained results are presented in table 3 and fig. 5 which clearly indicate that the simulate results very closely match with computed value.

From Fig 3 is failure rate diagram for a standby system with repair. During the analysis of the data collection I assume that the system has an invention and older one. They have failure rate and repair rate; the new invention has a failure rate (failure per day) of 0.01 and repair rate of 0.10. An older standby system has a failure of 0.00l while in standby and a failure rate of 0.10 when online. Now it is require solving for the system reliability for a planned 30-days use. This solution takes place as follows. This illustrative example is as like the system under study, i.e., a standby system with repair. The data regarding the constant failure and repair rates of this illustrative example have been used in the proposed MSD simulation model.

From the above analysis the productivity time increment has possibility with replacement instead of repairs.

It is clear from the results; the proposed system dynamics modeling framework can be used as an alternative approach to analyze the reliability of systems instead of using the Markov methodology alone which requires too many mathematical equations and calculates with unrealistic assumptions. It is worth mentioning here that the MSD modeling is much easier compared to the traditional approaches to study the reliability of complex systems.

Conclusively, for analyzing the dynamic behavior of systems, MSD simulation seems to be useful and also to understand the functioning and interaction of the different facets of reliability of systems. It can be stated that a switch from conventional methods to simulation seems to be the most promising reliability modeling and analysis strategy for systems.

CONCLUSIONS

In this work, a hybrid approach called as (Markov System Dynamic) MSD approach has been proposed for reliability analysis and to study the dynamic behavior of systems.

The proposed framework is illustrated in (Fig 1) for a standby system with repair. The results of the simulation when compared with those obtained by traditional Markov analysis clearly validate the proposed approach as an alternative approach for reliability analysis.

The procedure for the development of the MSD approach for this system is explained and the model is run to observe all its states. The proposed methodology is applicable for all types of failure rates and repair rates, and it is much simpler compared to traditional approaches. Further, this methodology can be used for studying various scenarios having managerial implications of system reliability. It is important to note that reliability declining of component or system has to be observed carefully to achieve the desired results. From the analysis of the component, i observe that not all the components can replace, and the reliability of some components is zero due to the failure rate. And also, the productivity time increment has possibility with replacement instead of repairs.

From this my work, I recommend managers must beware of the existing interdependencies within the component or system.

Accordingly, the model can be used as a simulation tool. Based on simulation analyses, managers can learn how to deal with such a comprehensive approach like the one investigated in this work. And, the different parties, i.e., engineers and machine operators, can jointly work with the model to understand the dynamic behavior of systems.

REFERENCES

[1] Forrester J.W. 1961. Industrial dynamics. MIT Press, Cambridge. pp.1-464.

[2] Goel L.R., Gupta R., Shrivastava P. 1990. Profit analysis of a two unit cold standby system with imperfect switch and varying physical condition of the repairman. *Microelectr. Reliab.* 30(4): pp.655–660.

[3] Gupta R., Goel L.R. 1991. Profit analysis of a two multicomponent unit standby system with MRT. *Microelectr. Reliab.* 31(1): pp.7–10.

[4] Gupta R, Mumtaz S.Z. 1996. Stochastic analysis of a two-unit cold standby system with maximum repair time and correlated failures and repairs. *J. Qual Maint Eng.* 2(3): pp.66–76.

[5] Islam A., Tedford D. 2012. Risk determinants of small and medium sized manufacturing enterprises (SMEs): an exploratory study in New Zealand. *J. Industrial Eng. Int.* 8:12. DOI:10.1186/2251-712X-8-12. pp.1-13.

[6] John E. Cook. 1965. The invention relates to a method and apparatus for controlling the cooling air on a Westlake glass blowing machine. Text book.

[7] Khalaj M., Khalaj F., Khalaj A. 2013. A novel risk-based analysis for the production system under epistemic uncertainty. *Journal Ind. Eng. Int.* 9:35. Doi:10.1186/2251-712X-9-35.

[8] Lal A.K., Gupta P., Sharma R.K., Singh J. 2005. Numerical analysis of reliability and availability of the serial processes in butter oil processing plant. *Int. J. Qual. Reliab. Manag.* 22(3):303–316

[9] Moafib S. E., Goel L.R, Gupta R. 1991. Comparison of two stochastic models for two-unit series system with cold standbys. *Microelectr Reliab* 31(6): pp.1105–1111.

[10] Mokaddis G.S., Tawfek M. L., Elyssia S.A.M. 1997. Cost analysis of a two dissimilar unit cold standby redundant system subject to inspection and two types of repair. *Microelectr. Reliab.* 37(2): pp.335–340.

[11] Mousavi S. M., Makui A., Raissi S., Mojtahedi S.M. 2012. A multicriteria decision making approach with interval numbers for evaluating project risk responses. *Int. J. Eng. Trans B.* 25(2): pp.121–129.

[12] Raissi S., Gatmiry Z. 2012. A six sigma approach to boost up time domain reliability in multi stage services. *African Journal of Bus. Manag.* 6(4): pp.1367–1374
[13] Richardson G.P. 1999. Reflections for the future of system dynamics. *Journal Oper. Res. Soc.* 50(4): pp.440–449.
[14] Robert S. Johnson & Robert D. Hall. 1992. Patent number: 5358542. Assigned to American National Can. Company. To Glass container forming machine including neck ring mechanism cooling.
[15] Song S.B., Deng Y.L. 1993. Reliability analysis of a three unit system in a changing environment. *Microelectr. Reliab.* 33(5): pp.637–640.
[16] Srinivasa Rao M., Naikan V.N.A. 2008a. A Markov system dynamics (MSD) approach for reliability analysis of systems. *Int. J. Commun. Dependab. Qual Manag.* 11(3): pp.17–30.
[17] Srinivasa Rao M., Naikan V.N.A. 2008b. A system dynamics based soft computing approach for reliability analysis of systems. In: Proceedings of the International conference ORSI, S.V. University, Tirupati, India, 62, RLT03.
[18] Srinivasa Rao M., Naikan V.N.A. 2008c. A soft computing approach for reliability analysis of repairable systems. In: Proceedings of the international conference ICAME, S.V. National Institute of Technology, Surat, India. pp.18–36.
[19] Srinivasa Rao M., Naikan. 2009a. A managerial tool for reliability analysis using a novel Markov system dynamics (MSD) approach. *Int. J. Managsci. Eng. Manag.* 4(3): pp.230–240.
[20] Srinivasa Rao M, Naikan V.N.A. 2009b. A novel Markov system dynamics framework for reliability analysis of systems. *Int. Journal Qual. Reliab* 24(1): pp.101–116.
[21] Srinivasa Rao M., Naikan V.N.A. 2009c. A Markov system dynamic (MSD) based availability and reliability analysis of a process industry. *Int. Journal Commun. Dependab. Qual Manag.* 12(3): pp. 26–49.

ANALIZA SISTEMA MEHANIZMA SA ROTACIONIM PRSTENOM

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Apstrakt: Proučavanje i analiza sistema mehanizma sa kružnim prstenom je važna tema u pouzdanosti. Analitičke tehnike postaju veoma komplikovane i nerealne, posebno za moderne složene sisteme.
U literaturi je bilo pokušaja da se razviju realnije tehnike i stopa otkaza i stopa popravke koristeći simulacioni pristup za analizu pouzdanosti sistema.
Ovaj rad predlaže hibridni pristup nazvan Markov sistemska dinamika (Eng. Markov system dynamics-MSD), koji kombinuje Markov system kao pristup, sa simulacionim pristupom sistemske dinamike za analizu pouzdanosti i za proučavanje dinamičkog ponašanja sistema.
Prikazani pristup ima prednosti i Markov sistemske metodologije. Predloženi okvir je za sistem mehanizma u stanju pripravnosti koji ima dve komponente, jednu u režimu pripravnosti, drugu u online režimu sa mogućnosti popravke.
Rezultati simulacije, u poređenju sa rezultatima dobijenim tradicionalnom Markov analizom, jasno potvrđuju pristup, Markov sistemsku dinamiku-MSD kao alternativni pristup za analizu pouzdanosti.

Ključne reči: *Simulacioni pristup, analiza pouzdanosti, dinamičke implikacije rezervnih sistema, Markov sistemski dinamički pristup, složeni sistemi.*

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DROPLET SIZE STATISTICAL ANALYSIS IN CHEMICAL CROP PROTECTION WITH UNMANNED AERIAL VEHICLE

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Abstract: The development of modern technologies in agriculture, particularly the use of unmanned aerial vehicles (UAVs), has enabled significant advancements in pesticide application, resulting in greater efficiency and precision in crop protection. This study aims to analyze the effects of various UAV flight parameters, specifically flight altitude, on droplet size and distribution uniformity. Field trials were conducted on the municipality of Zemun-Belgrade, Republic of Serbia, Latitude: North 44° 49' 22.2" and Longitude: East 20° 13' 19,2", with an altitude of 73 m. Different flight heights (1.5 m and 2.5 m) were tested at a constant flight speed of 3 m/s.

The results indicated that smaller droplets, generated at higher flight altitudes, contributed to more uniform droplet distribution, while larger droplets at lower flight altitudes ensured better coverage.

The most favorable outcomes were observed at a flight altitude of 2,5 m, where droplet distribution was both more uniform and of higher quality.

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These findings emphasize the importance of optimizing UAV flight parameters to enhance pesticide application, leading to improved precision, reduced pesticide use, and a lower risk of environmental contamination.

Keywords: *Volume median diameter (VMD), coverage, UAV systems, flight altitude, flight velocity, chemical protection, pesticides.*

INTRODUCTION

The main methods of crop protection include agrotechnical, mechanical, thermal, biological, and chemical approaches. Among these, chemical protection, relying on the use of pesticides, is considered the fastest and most effective. However, its efficiency depends on the proper selection of pesticides, application techniques, the technical system used, and the training of the operator [2]. Pesticides are mixtures of active substances intended for plant protection. Their application is typically classified based on the physical state of the substance being released from the technical system, distinguishing between solid, liquid, and gas formulations. It is crucial to note that the form in which the substance is emitted from the machine significantly influences application efficacy [2].

In addition to the physical state, droplet size is a key factor in successful chemical protection. Droplet size affects surface coverage, penetration, and the distribution of plant protection products. Accordingly, classification can also be made based on droplet size, which is closely related to the type of machinery and equipment used [2]. The droplet size classification is as follows [3]: spraying (>250 μm), misting (50–250 μm), fine misting (25–125 μm), and fogging (<50 μm). Droplet characteristics play a critical role in the efficacy of chemical crop protection, as droplet size directly affects deposition, coverage uniformity, and penetration into plant surfaces. Fine droplets facilitate deeper penetration and more uniform coverage, which is essential for achieving optimal biological efficacy. In contrast, larger droplets provide less uniform coverage but are less susceptible to off-target movement. Upon exiting the nozzle, droplets are typically spherical; however, during flight, aerodynamic forces cause deformation, often resulting in a flattened shape, which can enhance surface contact. Nevertheless, external factors such as wind can significantly influence droplet trajectory, leading to spray drift. Drift represents the fraction of the pesticide that fails to reach the intended target, posing risks to non-target areas and potentially causing phytotoxicity in adjacent crops. This phenomenon is particularly critical with smaller droplets, which are more easily displaced by air currents, thereby compromising application efficiency and environmental safety [3].

Another critical factor influencing the efficacy of chemical plant protection is the phenological stage of the crop, as the morphology and surface area of above-ground plant organs vary significantly throughout the growing season. These structural changes affect both the interception and retention of spray droplets. Therefore, achieving uniform and effective coverage across different growth stages, while maintaining a consistent application volume, is essential to ensure optimal pesticide performance and to avoid under or over application [3]. The choice and performance of pesticide application equipment are equally pivotal to treatment success.

Studies indicate that approximately 70% of application inefficiencies are attributed to the mismanagement of application technology. Specifically, 40% of failures are linked to suboptimal equipment functionality (e.g., nozzle wear, pump irregularities), while 30% result from improper handling or incorrect calibration by the operator.
The remaining issues arise from unsuitable pesticide selection and poorly timed applications, which can compromise efficacy and increase the risk of resistance development or environmental contamination [3].

The advent of modern technology, particularly in the context of precision agriculture, has enabled more efficient and site-specific management of key agronomic and environmental variables, ultimately supporting optimal crop growth and resource utilization. UAVs have proven to be one of the most influential technologies in precision agriculture and forestry, as they are highly versatile and adaptable and can improve the accuracy and timing of field operations [1, 12, 13, 14]. UAVs are currently used in a variety of agricultural applications, including remote sensing, field mapping, crop reconnaissance and chemical protection. Their ability to navigate complex terrain and execute pre-programmed flight paths makes them particularly valuable in regions where conventional ground-based machines are limited. Modern or advanced UAV spraying systems can carry up to 70 liters of pesticide solution and carry out treatments with high spatial accuracy, reducing labor demand, minimizing operator exposure to hazardous substances, and lowering the risk of unintended environmental contamination [4].

The advent of modern technologies, particularly in the area of labor requirements, minimizes operator exposure to hazardous substances and reduces the risk of accidental environmental contamination [4]. Compared to conventional spraying platforms, UAVs offer greater control over key operational parameters such as flight altitude, speed and nozzle configuration, which in turn significantly influence droplet formation, spray pattern uniformity and target coverage. Droplet size and its distribution pattern are critical factors for application effectiveness and drift potential [5]. This research investigated the relationship between drone flight altitude and droplet formation dynamics, focusing on volume median diameter (VMD or $D_{v0.5}$) and spray deposition efficiency. The study also sought to determine how the variation in flight altitude affects the homogeneity of droplet distribution over the target area.

MATERIALS AND METHODS

Field trials were conducted on the municipality of Zemun-Belgrade, Republic of Serbia, Latitude: North 44° 49' 22.2" and Longitude: East 20° 13' 19,2", with an altitude of 73 m. Different flight heights (1.5 m and 2.5 m) were tested at a constant flight speed of 3 m/s., overing a total area of 0,48 ha.

Collectors were positioned in three replications, with a 10 m buffer zone between each. In each replication, the collectors were positioned linearly over a 20 m stretch within the spray path, spaced at 0,5 m intervals. Each collector was equipped with a single water-sensitive paper (WSP) placed on top, enabling the assessment of spray deposition and coverage quality.

The experiment included two treatment variants (Table 1., Fig. 1), differing in UAV flight altitude while maintaining the same flight velocity. The spray volume was set at 30 l/ha, and the UAV operated with a spray swath width of 3,3 m. Each treatment was replicated three times.
For consistency, the UAV took off and landed at the same location for all repetitions. A solution consisting of water and red dye, commonly used in spray pattern analysis, was applied, with the dye added at a concentration of 450 g/ha.

Table 1. Summary of experimental treatments

Treatment	Technical system	Operating parameters
T1	Unmanned Aerial Vehicle	h = 1,5 m; v = 3 m/s
T2	Unmanned Aerial Vehicle	h = 2,5 m; v = 3 m/s

*h - flight altitude; v – flight velocity.

Technical system

In this study, the DJI Agras T30 UAV (Figure 1) was utilized for pesticide application in field conditions. The UAV is equipped with six electrically powered rotors and operates using high-capacity lithium-ion batteries (29,000 mAh, 22.2 V), enabling a maximum flight duration of approximately 15 min per charge. The system's maximum take-off weight is 66 kg, which includes a 30-liter chemical tank intended for liquid pesticide formulations. The spraying unit is powered by a diaphragm pump capable of delivering up to 7.2 L/min under a working pressure of approximately 0.3 MPa. The UAV is fitted with sixteen SX11001VS flat-fan nozzles, allowing for a consistent spray distribution across an effective swath width of 5 to 7 meters, depending on the pre-set flight speed and altitude. During application, the UAV operates at a height of 2.5–3.0 m above the crop canopy and at a maximum forward velocity of 7.0 m/s. Droplet size, expressed as volume median diameter (VMD), typically ranges between 150 and 250 µm and is influenced by nozzle type, operating pressure, flight dynamics, and ambient meteorological conditions. The T30 is integrated with advanced navigation systems, including GPS and real-time kinematic (RTK) positioning, ensuring high-precision autonomous flight. Real-time terrain adaptation is achieved through onboard radar and ultrasonic sensors that maintain a constant application height over variable topography. Additional safety features include an obstacle-avoidance system and an automatic return-to-home function activated in case of low battery or signal loss. The onboard control unit dynamically adjusts spraying parameters in response to real-time environmental data, aiming to enhance deposition uniformity while reducing off-target drift and environmental exposure.

Figure 1. UAV system for pesticide application in wheat fields

Data Collection and Analysis

WSPs served as artificial collectors for droplet deposition assessment. The collected samples were scanned in grayscale at a resolution of 600 DPI to obtain digital records of spray coverage. Image processing and analysis were conducted using DepositScan™ software, which enabled the quantification of deposition parameters, including droplet density per unit area, percentage of surface coverage, and droplet size distribution [11]. The classification of droplet spectra was determined based on VMD and droplet diameter (DD), following the criteria outlined by Matthews [12].

To evaluate the uniformity of droplet deposition across different sampling points, the coefficient of variation (CV) was calculated. The distribution of spray droplets plays a key role in ensuring even pesticide coverage across the target surface. In this study, the uniformity of droplet deposition was analyzed based on variations in deposition patterns, droplet density, and surface coverage. A lower CV value indicates a more uniform distribution of droplets. The coefficient was calculated using [10], the following equations:

$$CV = \frac{SD}{M} * 100\% \quad \text{and} \quad SD = \sqrt{\sum_{i=1}^{n}(x_i - M)^2/(n-1)}$$

Where is,
SD - represents the standard deviation,
M - denotes the mean droplet deposition value,
x_i - refers to the number of droplets per square centimeter of WSP,
n - the total number of WSP collectors used in each UAV treatment.
During data processing, the following parameters were specifically evaluated [7]:

- $D_{v0.1}$ represents the droplet diameter below which 10% of the total spray volume is contained. It reflects the presence of very fine droplets in the distribution
- $D_{v0.5}$ (VMD) is the droplet diameter below which 50% of the spray volume resides. It serves as the median value, indicating that half of the total volume is composed of droplets smaller than this diameter, and half larger
- $D_{v0.9}$ corresponds to the droplet diameter below which 90% of the total spray volume is found. It provides insight into the coarseness of the spray, capturing the contribution of larger droplets

- RS (Relative Span) is an index describing the width of the droplet size distribution. It is calculated using the formula:

$$Rs = \frac{Dv0.9 - Dv0.1}{Dv0.5(VMD)}$$

A lower RS value indicates a narrower and more uniform droplet size distribution, which is generally desirable for consistent spray coverage.

Conversely, higher RS values reflect greater variability in droplet sizes, which may negatively affect application uniformity [7]. The data were analyzed using one-way analysis of variance (ANOVA) in the statistical software IBM SPSS Statistics (version 29.0.1.0). Where significant differences were observed, post hoc comparisons were performed using Student's t-test to determine pairwise differences between treatment means.

Before the statistical analysis, assumptions of normality and homogeneity of variances were tested using the Shapiro–Wilk and Levene's tests, respectively.

If necessary, coverage and droplet size data were subjected to appropriate transformations (e.g., log or square root) to meet the assumptions of parametric analysis. All results are reported as mean values (M) accompanied by standard deviations (SD). A significance level of $p < 0,05$ was considered statistically significant for all tests.

RESULTS AND DISCUSSION

Following the placement of collectors and water-sensitive papers at predefined field locations, application was performed using the UAV system. Upon completion, WSP papers were carefully retrieved and transported to the laboratory for subsequent analysis.

Statistical analysis of the collected data was conducted using IBM SPSS Statistics. A one-way analysis of variance (ANOVA) was employed to assess differences between treatment groups, with the results summarized in Table 2. Statistically significant differences were observed between treatments T1 and T2 for the VMD ($F = 6,430$; $p = 0,012$) and for $D_{v0.9}$, representing the droplet diameter below which 90% of the spray volume is contained ($F = 4,273$; $p = 0,041$). These findings indicate that flight altitude had a measurable impact on both the central tendency and the upper bound of droplet size distribution. To further elucidate the nature of these differences, pairwise comparisons were conducted using Student's t-test, focusing specifically on the VMD and $D_{v0.9}$ parameters.

On the other hand, no statistically significant differences ($p > 0,05$) were detected between treatments for the remaining evaluated parameters, suggesting that flight altitude did not have a pronounced effect on other aspects of droplet characteristics under the given experimental conditions. Nevertheless, despite the absence of statistical significance, the observed mean values indicates a consistent trend that may point to potential differences in spray performance depending on flight altitude. These tendencies, while not statistically confirmed, may still carry practical relevance, particularly in the context of optimizing UAV application protocols for enhanced efficacy in plant protection. Such findings underscore the importance of considering both statistical outcomes and biological or operational implications when interpreting field trial results, especially when aiming to refine UAV-based spraying strategies in diverse crop production systems.

Table 2. ANOVA results for spray deposition parameters

Factor	Parametars	DF	SS	F	*p*	Sig.
Flight height	Coverage	1	0,372	0,112	0,739	NS
	VMD	1	8181,22	6,430	0,012	*
	$D_{v0.1}$	1	2121,34	2,743	0,100	NS
	$D_{v0.9}$	1	322747,1	4,273	0,041	*

*Note: *p* represents the significance level of the factor affecting the result. $p < 0,01$ (**) indicates that the factor has a highly significant impact on the test result, $p < 0,05$ (*) indicates that the factor has a significant impact on the test result, and $\boldsymbol{p} > 0,05$ (NS) indicates that the factor does not have a significant impact on the test result.

Results from Student's t-test confirmed that flight altitude had a statistically significant effect on both the VMD ($p = 0,012$) and $D_{v0.9}$ ($p = 0,042$), as shown in Table 3. These findings suggest that variations in UAV flight altitude can meaningfully alter droplet size characteristics during application. Analysis of mean values revealed that VMD decreased at higher flight altitudes, indicating the generation of finer droplets. This droplet profile may enhance coverage uniformity across the leaf surface and improve deposition on the target area, contributing positively to treatment efficacy. However, finer droplets are also more prone to spray drift, particularly under windy conditions, which introduces a potential risk for off-target contamination. A similar trend was observed for $D_{v0.9}$, with lower values recorded at higher altitudes. This further supports the conclusion that increased altitude results in a higher proportion of fine droplets within the overall spray volume. Such a distribution affects not only the biological efficacy and application precision but also the environmental safety of the treatment. Taken together, these results highlight the critical role of UAV flight altitude in shaping important technical parameters of pesticide application. Optimizing flight altitude is thus essential for balancing treatment effectiveness with drift reduction, ultimately supporting the goals of precision agriculture and sustainable crop protection practices.

Table 3. Comparison of VMD and $D_{v0.9}$ between treatments (t-test results)

Parameters	t	d.f.	p^*
VMD	2,536	122,31	0,012
$D_{v0.9}$	2,067	71,60	0,042

**p* values less than 0,05 indicate a statistically significant difference.

Table 4., presents the mean values of all evaluated parameters, offering a comprehensive overview of application performance under different flight altitudes. The data indicate that at higher flight altitudes, the VMD was lower, suggesting the formation of finer droplets.

This was accompanied by a slight reduction in overall spray coverage, likely influenced by increased droplet dispersion due to higher release height and enhanced exposure to external factors such as wind and air turbulence.

However, this difference was not statistically significant. In contrast, lower flight altitudes resulted in larger VMD values, indicating the generation of coarser droplets. These larger droplets contributed to higher total coverage, but at the expense of uniformity, as evidenced by an increased CV.

Moreover, the RS, a measure of droplet size distribution uniformity, was lower at higher altitudes, reinforcing the observation that finer droplets were more evenly distributed across the treated surface. This finding is particularly relevant in the context of chemical application effectiveness, as uniform droplet distribution is essential for achieving consistent coverage and ensuring reliable protection across the entire target area.

Table 4. Mean values of spray application parameters by treatment

Treatment	Coverage (%)	VMD (µm)	$D_{v0.1}$ (µm)	$D_{v0.9}$ (µm)	RS
T1 (I)	5,82±3,25	273,62±27,95	129,48±11,44	594,95±91,80	1,72
T1 (II)	5,09±2,63	247±31,14	125,47±12,93	517,57±84,62	1,61
T1 (III)	3,67±2,16	281,09±32,52	128,81±9,95	611,62±123,64	1,71
T2 (I)	4,70±2,03	242,71±29,75	117,66±10,42	502,76±94,62	1,58
T2 (II)	4,99±1,13	232,09±27,26	115,47±8,41	467,095±63,36	1,52
T2 (III)	4,37±1,48	278,51±39,16	138,38±15,27	593,47±109,31	1,64

Figure 1., illustrates the mean values of the CV for spray coverage across treatments and replications. The results demonstrate that droplet distribution was notably more uniform at the higher flight altitude, whereas at the lower altitude, the CV exceeded 50%, indicating uneven and inconsistent deposition of the spray solution. This parameter is directly linked to the effectiveness of chemical crop protection, as high variability in coverage can compromise treatment efficacy and lead to insufficient pest or disease control. Although a lower VMD was recorded at the higher flight altitude, typically associated with finer droplets and improved spreading capacity, the data suggest that environmental factors, such as wind influence or UAV flight velocity, may have contributed to slightly reduce total coverage. Nonetheless, despite the marginally lower coverage, the distribution uniformity was superior at the higher altitude, as evidenced by the reduced CV values. This indicates a more consistent deposition pattern across the treated surface, which is critical for achieving uniform protection and minimizing untreated zones.

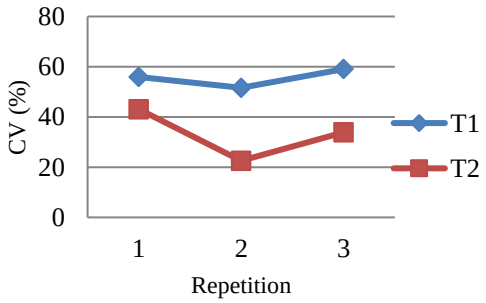

Figure 1. Droplet distribution by tested treatments based on the coefficient of variation

The findings of this study are in alignment with previous research investigating the influence of UAV flight altitude on the efficacy and uniformity of pesticide application. For instance, [9], reported poor droplet distribution uniformity at a flight height of 1 m, with the coefficient of variation (CV) exceeding 80%, significantly higher than that observed with conventional backpack sprayers [9].
Similarly, the present study recorded a CV greater than 50% at a flight altitude of 1,5 m, reinforcing the observation that lower flight altitudes may lead to uneven deposition patterns.
In a related study, [8] found that higher UAV flight altitudes (3–5 m) were associated with lower VMD values, leading to more uniform droplet distribution and improved coverage of lower leaf surfaces [8].
These findings are consistent with the current results, where higher flight altitude was linked to finer droplets and a more stable distribution across the treated area. However, it is critical to emphasize that finer droplets, while beneficial for coverage and canopy penetration, are also more susceptible to aerial drift, particularly under increased wind speeds. This underscores the importance of carefully calibrating UAV flight altitude and other operational parameters to balance application efficacy with environmental safety, thereby minimizing off-target deposition and pesticide loss.

CONCLUSION

The results of this study demonstrate that UAV flight altitude significantly influences key technical parameters of pesticide application, which in turn affect the overall quality of chemical crop protection. Statistical analyses, including ANOVA and Student's t-test, revealed significant differences in VMD and $D_{v0.9}$ values between treatments with differing flight altitudes. Lower VMD and $D_{v0.9}$ values recorded at higher flight altitudes indicate the formation of finer droplets, which may enhance droplet spread ability and surface coverage. However, these finer droplets are also more susceptible to spray drift, potentially reducing total coverage under suboptimal conditions.
Although no statistically significant difference was observed in total coverage between treatments, CV and RS values were lower at higher altitudes, indicating improved droplet distribution uniformity, a factor critical for achieving consistent and effective protection across the crop canopy.
These findings underscore the importance of precisely calibrating UAV flight parameters to balance three competing factors: coverage, distribution uniformity, and drift risk. UAV-based pesticide application presents significant potential for improving treatment efficiency and contributing to the sustainability of modern agriculture. However, to fully realize these benefits, continuous optimization of flight settings and integration of advanced technologies within precision agriculture frameworks are essential. Future research should expand to include additional operational variables, such as nozzle type, droplet velocity, and meteorological influences, in order to develop a more comprehensive understanding of conditions that ensure safe, efficient, and effective UAV-based pesticide application.

REFERENCES

[1] Borikar, G., Gharat, C., Deshmukh, S. 2022. Application of Drone Systems for Spraying Pesticides in Advanced Agriculture. A review. IOP Conference Series: Materials Science and Engineering, Vol.1259, doi:10.1088/1757-899X/1259/1/011001.

[2] Sedlar, A., Bugarin, R., Đukić, N. 2014. Tehnika aplikacije pesticida. Univerzitet u Novom Sadu, Udžbenik, Poljoprivredni fakultet. ISBN 978-86-7520-328-5. pp.1-212.

[3] Urošević, M., Dimitrijević, A. 2016. Mašine za primenu pesticida. Univerzitetski udžbenik. Univerzitet u Beogradu, Poljoprivredni fakultet. pp.1-307.

[4] Hafeez, A., Husain, M.A., Singh, S.P., Chauhan, A., Khan, M.T., Kumar, N., Chauhan, A., Soni, S.K. 2023. Implementation of drone technology for farm monitoring & pesticide spraying: A review. Information Processing in Agriculture, 10(2), pp. 192–203.

[5] Bošković, B., Božić, D., Pajić, M., Marina, I., Buđen, M. 2023. Primena kombinacije herbicida tritosulfuron i florasulam bespilotnom letelicom u usevu ozime pšenice. Acta herbologica, vol. 32, br.2, pp. 137-150. doi: 10.5937/32ah-47162 .

[6] Čolaković H. 2021. Uzgoj pšenice na OPG-u "Čolaković" - Vinkovci u sezoni 2019/2020. Završni rad, Sveučilište Josipa Jurja Strossmayera u Osijeku, Fakultet agrobiotehničkih znanosti Osijek. https://urn.nsk.hr/urn:nbn:hr:151:775845. pp.1-23.

[7] Pompe, J.C.A.M., Holterman, H.J., Van Straelen, B.C.P.M. 1992. Technical aspects of pesticide application. Wageningen Agricultural University, Department of Agricultural Engineering and Physics. Report 92-11, pp. 1-83.

[8] Yu, J., Xu, X., Duan, J., Jiang, Y., Yuan, H., Liang, H., Jing, S., Yang, Z. 2025. Effect of operational parameters on droplet deposition characteristics using an unmanned aerial vehicle for banana canopy. Frontiers in Plant Science, vol.15, pp.1-15. doi: 10.3389/fpls.2024.1491397.

[9] Wang, G., Lan, Y., Yuan, H., Qi, H., Chen, P., Ouyang, F., Han, Y. 2019. Comparison of spray deposition, control efficacy on wheat aphids and working efficiency in the wheat field of the unmanned aerial vehicle with boom sprayer and two conventional knapsack sprayers. Applied Sciences, 9(2), p.218. https://doi.org/10.3390/app9020218. pp.1-16.

[10] Chen, P., Ouyang, F., Wang, G., Qi, H., Xu, W., Yang, W., Zhang, Y., Lan, Y. 2021. Droplet distributions in cotton harvest aid applications vary with the interactions among the unmanned aerial vehicle spraying parameters. Industrial Crops and Products, vol.163. pp.1-9. https://doi.org/10.1016/j.indcrop.2021.113324.

[11] Zhu, H., Salyani, M., Fox, R.D. 2011. A portable scanning system for evaluation of spray deposit distribution. Computers and Electronics in Agriculture, 76, pp. 38–43.
Matthews, G.A., Roy Bateman 2025. Pesticide application methods, 3rd ed. Oxford, UK: Blackwell Science, ISBN-10 1394262205:, ISBN-13 : 978-1394262205. pp.1-256.

[12] Oljača, V.M., Pajić, M., Gligorević, K., Dražić, M., Zlatanović, I., Dimitrijević, A., Miodragović, R., Mileusnić, Z., Radojević, R., Živković, M., Petrović, D., Radivojević, D., Urošević, M., Topisirović, G., Radičević, B., Ećim, O., Balać, N. 2018. Dizajn, klasifikacija, perspektiva i moguća aplikacija dronova u poljoprivredu Srbije. Poljoprivredna tehnika, 43(4), pp. 29–56.

[13] Gligorević, K.B., Dražić, M.S., Pajić, M.B., Šunjevarić, M.V., Bošković, B.D., Oljača, V.M. 2024. Pregled mogućnosti primene nekih tehnologija nano dronova u savremenoj poljoprivredi. Poljoprivredna tehnika, 49(1), pp. 75–96.

[14] Ilić, D., Ilić-Kosanović, T., Milošević, I. 2024. Primena dronova u zaštiti od šumskih požara – bazične strategije za Republiku Srbiju. Serbian Journal of Engineering Management, 9(2), pp. 30–36.

STATISTIČKA ANALIZA VELIČINE KAPLJICA U HEMIJSKOJ ZAŠTITI BILJA KOD PRIMENE BESPILOTNIH LETELICA

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Apstrakt: Razvoj savremenih tehnologija u poljoprivredi, a naročito primena bespilotnih letelica (UAV sistema), omogućio je značajan napredak u primeni pesticida, doprinoseći većoj efikasnosti i preciznosti u zaštiti bilja.

Cilj ovog istraživanja bio je da se analizira uticaj različitih parametara leta UAV sistema, pre svega visine leta, na veličinu kapljica i ujednačenost njihove raspodele.

Terenski ogledi sprovedeni su na području opštine Zemun-Beograd, Republika Srbija , geografska širina: Severno 44° 49' 22.2" i geografska dužina: Istočno 20° 13' 19,2", na nadmorskoj visini terena od 73 m.

Ispitivane su dve visine leta bespilotne letelice DJI Agras T30 UAV (1,5 m i 2,5 m) uz konstantnu brzinu leta od 3 m/s.

Rezultati statističke analize su pokazali da manje kapljice, koje nastaju pri većim visinama leta, doprinose ujednačenijoj raspodeli, dok veće kapljice na manjim visinama obezbeđuju bolju pokrivenost ciljne površine. Najpovoljniji rezultati postignuti su na visini leta od 2,5 m, gde je zabeležena bolja ujednačenost i viši kvalitet raspodele kapljica.

Dobijeni rezultati ukazuju na značaj optimizacije eksploatacionih parametara UAV sistema u cilju povećanja efikasnosti primene pesticida, smanjenja njihove potrošnje i umanjenja rizika od zagađenja životne sredine.

Ključne reči: *Srednji prečnik kapljice (SPK), pokrivenost, UAV sistemi, visina leta, brzina leta, hemijska zaštita, pesticidi*

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