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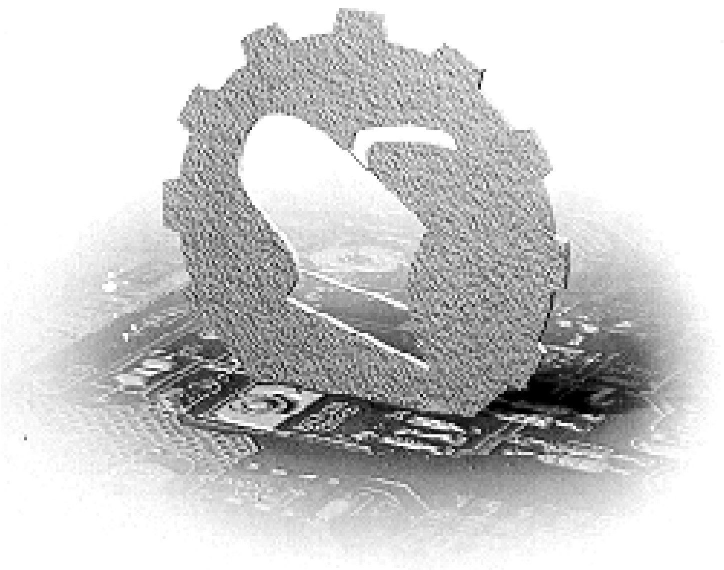

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A REVIEW OF COMMON NATURAL VENTILATION AND EVAPORATIVE COOLING SYSTEMS FOR GREENHOUSES AND THE NIGERIAN REALITY

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Abstract: Greenhouses simulate the “desired” environment for successful growth and development of plants. They, by design, achieve this desired environment by supplying the necessary climatic inputs needed by the plants to strive and at the same time exclude factors impeding the growth of plants, hence it is called a controlled environment. One of the common and most desired attribute of the greenhouse is its ability to provide effective cooling to the plants. This paper reviewed, extensively, the concept of Evaporative cooling as applied in greenhouses. Factors like Vapor Pressure deficit (VPD), Relative Humidity, Ambient Temperature were also discussed with regards to its effects on the efficiency of the Evaporative cooling system. The efficiencies of the Fan and Pad System and the Fog systems were reviewed and compared with their consequent dependence on factors like nozzle spacing, nozzle length, saturation efficiency of pad material etc. The Natural Ventilation method was also reviewed as a “stand alone “ greenhouse cooling method and as an augmentation to other cooling systems. Factors like rate of air exchange, total area of vents, wind speed, vent opening angles etc. were also discussed in line with their effects on the effectiveness of the Natural ventilation method. The Nigerian Perspective on Greenhouses and its Cooling methods was also discussed with reference to local development of evaporative coolers as well as its importation, its affordability, management, availability and appliance to the Nigerian farming culture.

Key words*: ambient temperature, evaporative cooling, fan and pad cooling, fog cooling, greenhouse, relative humidity.*

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INTRODUCTION

Greenhouses are designed to create a controlled environment for plant growth. Their basic objective is to provide a congenial internal microclimate that optimizes plant growth. [1]. Greenhouses are complex thermodynamic systems where indoor relative humidity and temperature are regulated in order to facilitate plant growth and production. [2].

Greenhouses and other indoor plant factories are one of the many alternative ways of fulfilling the food demands for the urban populace, [3]. Greenhouse cultivation has advanced from simple open field crop planting to very urbane environment agriculture (CEA) facilities that launched the image of plant factories for urban agriculture. These advances have furthered scientific innovations for efficient plant production in populated cities and multi storey buildings, [4]. Improvements in low cost greenhouse design has the prospect of increasing food security especially in areas where global climate is increasingly contributing to the irregularities in local weather patterns, [5]. Due to obstacles presented by harsh climate and water deficit in greenhouse all year-round cultivation, greenhouses should be designed to provide adequate control of its own microclimate, such as relative humidity, CO_2 concentration, temperature and lightening depending on ambient conditions and type of cultivation.[6]. Microclimates in greenhouses can be influenced by control actions like ventilation, heating, carbon dioxide enrichment to provide suitable environmental conditions for crops. [7]. Consequently, greenhouses are basically designed to withstand the dangers of external factors, environmental factors and internal loads as well as maximizing solar radiation available for the crop.[8]. Even though greenhouse technology is a practicable route to sustainable crop production in regions with adverse climatic conditions, high summer temperatures impede the successful year crop production, [9] Similarly, greenhouse cultivation in hot climatic regions is usually characterized by high solar thermal load which founds major problems inside the greenhouse environment and limits plant growth. [10]. This is why climate control in greenhouses is currently one of the major goals of engineering in precision agriculture [11]. Continuous positive air movement inside a greenhouse is very crucial to plant growth as it balances carbon dioxide, temperature and humidity levels inside the greenhouse, [12]. Greenhouse cooling is an essential factor to be considered in the design of a greenhouse and could be achieved by natural or artificial methods. Since air speed distribution is a major factor affecting greenhouse heat and mass transfer, [13], natural ventilation in greenhouses is usually achieved by air exchanges through multiple controlled openings.[11] The rate of exchange of air through natural convection (which is a very crucial factor in naturally ventilated greenhouses) is a factor of the external and internal wind speed and temperature differences of the greenhouse as well as the total area of vents. However, in very hot areas with low air speeds, natural ventilation becomes very challenging hence the need for artificial cooling systems in greenhouses. Since it is imperative to cool greenhouses in hot summer seasons and natural ventilation cannot occur without wind or at temperatures above 32^{o}C, forced ventilation was adopted. Forced ventilation can be introduced using fans and blowers but the inefficiency of fans and blowers to remove inside hot air in closed greenhouses in peak summer led to the introduction of other methods like fan and pad systems and fogging systems [14].

Semiarid climate regions have great potential for productivity due to the large amounts of solar radiation received throughout the year but these regions are also constrained by excessive air temperatires and limited water use. However , optimization of ventilation with use of cooling systems e.g the fog cooling system with natural ventilation will present a more conducive growing environment for plants in such regions and also allow for less water use [15]. According to [16], each cooling systems has its own limitations. Combining two or more cooling systems will more likely meet the cooling demands for greenhouses in tropical areas.
Therefore, selection and implementation of the microclimate cooling methods in greenhouses should suit the crop, the type of measurement and the cost proposed for the greenhouse [17], [18], listed natural ventilation, shading and evaporative cooling as the three most commonly used engineering techniques in controlling the micrclimate of a greenhouse under cropped conditios. However for the purpose of this work, natural ventilation and evaporative cooling methods will be reviewed

Evaporative Cooling

Evaporative cooling basically is the removal of air latent heat by liquid water (which evaporates into vapor) thereby increasing the relative humidity of air while it is cooled [19]. Evaporative cooling can also be defined as a process that reduces air temperature by evaporation of water into the airstream. Energy lost from the air due to the water evaporation causes the air temperature to drop [20]. Evaporative cooling facilitates the removal of sensible heat from inside a greenhouse, [18]. [19] further noted that during evaporative cooling, the relative humidity and dry-bulb temperature of the external air influence the cooling efficiency as well as other factors like system control strategy, atomization capacity of spraying nozzles, ventilation mode and water quality parameters. Among the several techniques of greenhouse cooling, evaporative cooling has transformed the innovation of cooling systems in greenhouses since the ninteenth century and is still in use around the world [10]. Evaporative cooling can either be Direct Evaporative cooling (DEC) or Indirect Evaporative Cooling (IEC), [21] characterised direct evaporatve cooling as being based on the thermal and mechanical contact between air and water and indirect evaporative cooling as being based on heat and mass transfer between two streams of air, seperated by a heat transfer surface with the dry side where air is cooled and the wet side where air and water are cooled. According to [22], the direct evaporative cooling process involves contact of water and air in cross-flow arrangement with the horizotal channels for air and the vertical channels for water. Warm air is drawn by a fan through a porous wetted pad,the drawn water absorbs heat and evaporates through a porous wetted medium with air finally leaving the system ata a lower temperature. The porous pads are continously wetted by the water sprayed on the pad surface thereby maintaining the wet bulb temperature at a constant. Examples of the direct evaporative systems are the Fan and Pad evaporative systems and the Fogging/Misting process which are the most commonly used cooling systems in greenhouses.

Fog cooling Method

Fog cooling is simply based on the dispersion of fine water into the air stream in order to increase the rate of heat exchange between water an air, [23].

According to [10], fogging system of cooling sprays water into the airstream as fine droplets (in the range of 2-60µm in diameter) in which direct contact with water in the air takes place.

Cooling is achieved by the evaporation of the sprayed water droplets (usually with diameter of 2-60µm), [24]. In Israel for example, fog systems can provide a wide range of desired temperatures and relative humidities in greenhouses during most months of the year with only a minor influence on the radiation levels inside the greenhouse. [25]. [1], in their review of the ventilation and cooling technologies in agricultural greenhouse application concluded that fogging and misting systems effectively lower temperatures up to 5-6 ^{o}C below the ambient temperatue and also provide more uniform temperature and humidity levels inside the greenhouse when compared to the fan and pad evaporative cooling system. Evaporative fogging systems have been increasingly implemented in Arid and Semi Arid regions to increase production cycles in very warm seasons and also to achieve near-optimum environments for all year-round production. [8]. To design a fogging system that will provide good control of the inside environmental conditions and a good crop yield of high quality produce, the ventilation characteristics of the greenhouse has to be determined, [26]. These ventilation characteristics could be temperature, relative humidity, the specific heat, heat transfer coefficient and viscosity of air amongst many others.

Fig. 1. Inside an experimental greenhouse with fog cooling system in University of Arizona, Source: [15], [23] presented a thermal model proficient in the prediction of the thermal environment inside greenhouse under different fogging configurations. A fog-cooled naturally ventilated greenhouse at Coochbehar, West Bengal, India (Latitude: 26.2N and Longitude :80E) was used for the experiment.

The model presented is as follows:

$$M_g C_p \frac{dT}{dt} = Q_{in} - Q_{cover} - Q_{vent} - Q_{latent} - Q_{temp} \quad (1)$$

Where:
M_g – mass of greenhouse air
C_p – specific heat of greenhouse air
T - temperature of the greenhouse air
Q_{in} – input solar energy to the greenhouse air
Q_{cover} – convective heat losses through the greenhouse cover
Q_{vent} – heat exchange due to air infiltration through the greenhouse ventilators
Q_{latent} – heat transfer due to fog evaporation
Q_{crop} – energy exchange due to crop transpiration

After intemittently cooling the greenhouse with three distinct fogging cycles, it was observed that fogging spray time and spray interval combination influence the cooling performance of the fogging system and that suitable fogging cycle can maintain greenhouse temperatures 2-4^{o}C below ambient temperature and also the relative humidity of the greenhouse within a satisfactory level.

Similarly, [27], studied the effects of micro-fog systems in greenhouse environments and tomato *(Solarum Lycopersicum L.)* productivity in summer seasons and observed that mean air temperature and vapour pressure deficit (VPD) were reduced by 3.2^{o}C and 1kPa respectively with micro-fog treatment in the greenhouse. Also relative humidity was increased by 13.3% in the micro-fog treated greenhouse. Significantly higher stomatal density and index and increased stomatal conductance and photosynthesis rates were recorded for the micro-fog treated plants. There was also a reduction in transpiration rates for the plants in the micro-fog treated greenhouse thereby ensuring maximum water use by the plants. The marketable yield of the tomato was increased by 12.3% due to the micro-fog treatment.The effects of a fogging system in a miltispan plastic greenhouse in Cukurova region of Yernice-Adana, Turkey, was investigatd by[26]. The fogging system design investigated consists of three nozzle lines with 82 fog generating nozzles each, with a nozzle spacing of 2.5m. the efficiency of the fogging system was characterised base on air flow rate and evaporation and was calculated to be averagely 50.5% but with lower outside relative humidity the efficiency increased up to 80%. The fogging system was also observed to reduce the ambient temperature by 6.6 ^{o}C inside the greenhouse and increase the relative humidity by 25% on the average. The average airflow rate was 98kg/h.m^2 while the average evaporation rate was 483kg/h.m^2. A different approach of evaluating the fogging system in greenhouses was adopted by [28]. The approach was to evaluate the fogging system by calculating the fraction of water that evaporated from the fog generating nozzles. After studying the fogging system performance for two distinct fogging durations and at different fogging intervals, it was observed that the fogging system dropped up to 4 ^{o}C of temperature inside the greenhouse when used 1.5mins duration and 4.5mins interval. With emphasis on the role of fogging intervals in the performance evaluation of the fogging system, [10], assesed the fog system with solar chimney assisted ventilation in a circular greenhouse and observed that during peak ambient temperatures, optimised fogging with spray intervals of 1.5 mins -2mins was able to succesfully lower temperature by 4 ^{o}C to 6 ^{o}C below the ambient temperature. Also [29] while simulating the air temperature and humidity distribution for greenhouses adopting fog cooling systems (using FLUENT, CFD program) observed that the experimental fog cooling system used performed best at a height of 2.3m from the floor and 1.9m from the sidewalls with nozzle spacing of 3.7 m.

Furthermore, [33], noted in their review of the effects of cooling strategies on the uniformity and microclimate of greenhouses, that the spatial distribution of temperature and relative humidity depends on the amount of spread water fog, fogging and interval times and evaporation mechanism in fog cooled greenhouses.

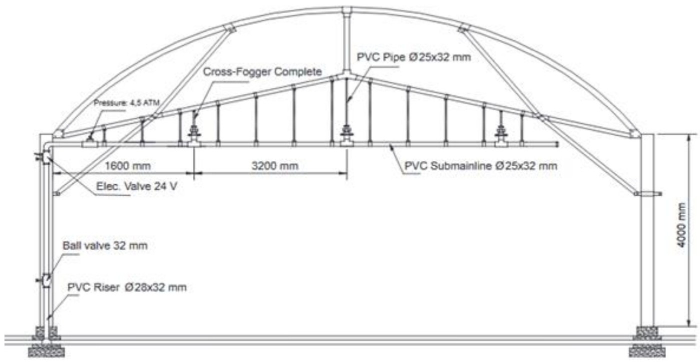


Fig. 2. Plastic greenhouse with a fogging system, [26].

- Most greenhouse fog cooling systems are not 'stand-alone' systems, they are paired with either natural or forced ventilation (usually using fans or blowers). These ventilation systems help in circulating the air cooled by the fogging system as well as expelling the hot air from the greenhouse. A good example is the experiment by [15] on the demonstration of the feasibility of maintaining relative humidity and temperature simultaneously within a desirable range and at the same time reducing the water used for fog cooling in a a single span greenhouse at the University of Arizona using a simple and unique alogrithm for fogging and ventilation inlet openings. The experiment was carried out using 68 fog nozzles with 0.2mm orifice size and 0.30m spacing. Tomato crop was planted and the transpiration rate and water balance were investigated and the following observations made. A 13% decrease in water use was recorded when the ventilation rate was reduced by reducing the inlet openings
- Transpiration rate increased linearly with and increase in vapour pressure deficit (VPD) of air
- VPD also decreased with decrease in canopy transpiration but was greater than the fog evaporation rate under same conditions with relative humidity ranging from 70-94%

Another example of a natural ventilation plus fog system method is the Natural Ventilation Augmented Cooling systems(NVAC), one of which was used by (McCartney, et al., 2018) in investigating the cooling performance and airflow patterns in an NVAC greenhouse. In the 1:4 model single span greenhouse, a temperature reduction of 1.9-12.6^{o}C and relative humidity increase of 1.4-31.2 % were observed. Also, a vapour pressure deficit of 0.3-4.9 kPa and air movements at velocities up to 0.38ms^{-1} (without the use of fans) were recorded.

The NVAC system increased the air turbulence from 0.19 to 0.32 inside the greenhouse. Similarly, [30] investigated the effect of natural ventilation rates on humidity and water use for fog cooling using a single span, double-polyethylene greenhouse without plants.

With an air temperature set poit of 24.5 °C and fogging operated cyclically, the fog generated ws collected and measured at 15 minuites intervals. From the results, it was observed that water used increased in line with a decrease in relative humidity inside the greenhouse as well as with increase in the ventilation rate. Humidity decreased from 80-655 when the ventilation rate was raised from 1-3.5$m^3m^{-2}min^{-1}$ and at 18-21$gm^{-2}min^{-1}$ water use increased. A control alogrithm used to incorporate the alteration of the vent openings showed the feasibility of maintaining air temperature and relative humidity at good ranges of 24-25 °C and 65-75% respectively while reducing the water used for fog cooling.

Another feature of recent greenhouse fog cooled systems is the use of control models, alogrithms to run the fog system and give responses regarding the environmental conditions of the greenhouse. An exapmle of this control logic was designed by [31] for a high pressure fog cooling system used with natural ventilation in a greenhouse. The program computes suitable duration of the fog cooling system operations, reads the dry bulb temperatureset point inside the greenhouse for the fogging system operation and the target relative humidity defined by the user. It also displays relevant output information to the user and has been found to give correct responses even during rapid changes in environmental conditions. It was also observed that as the vapour pressure deficit decreased, the duration of the fog cooling system operation decreased. A different control alogrithm using a variable pressure fogging(VPF) system against the conventional on/off fixed pressure fogging system based on vapour pressure deficit(VPD) system was developed by [32] and compared to the VPF system. It was observed that the VPF system consumed less water and energy than the VPD system. Also stability of relative humidity and temperature were achieved as well as small pump cycling using the VPF system. Similarly, a Non Linear Autoregressive with Exogenous Input (NARMX) system was used by [8] to optimise the control actions (vent opening and fogging rate) of a single span (270 m^2) greenhouse in the University of Arizona Controlled Environment Agricultural Center before implementation into the Neural Network (NN) predictve control scheme as a preparatory method.

Admist the advances made in greenhouse fogging and the efficiencies recorded, fogging systems operate with some technical restraints. According to [33], Greenhouse fogging systems face the problems of clogging of nozzles due to high salinity of water which in turn leads to increase in microclimate distribution in the greenhouse. In maintaining greenhouse temperatures at it's optimum range in periods of high radiation. [34], observed that single-fluid nozzle fog colling systems hardly maintain greenhouse temperatures at optimum ranges in summer due to its low cooling efficiency and also exposes the crops to the risk of pathogen invasion which usually occurs due to excessive wetting of plant foilage. In contrast to the above, [35] proposed continous spraying in fog cooled greenhouses as a proficient way of maintaining good greenhouse temperatures.

He observed in an experiment carried out to control the fog-generation rate and fan speed with inverters in an experimental greenhouse installed with fog cooling systems and fans (with the inverters connected to each of the devices based on the outside and inside environmental conditions), that the system produced continous fog spraying which aided in the control of the greenhouse inside air temperature with less energy consumption and low water use.

Fan and Pad Cooling Method

Fan and pad cooling system comprises of induced draught fans installed on one side of the greenhouse wall and a cooling pad on the opposite side of the wall. The cooling pad is kept wet by circulating water through it(using a pump) as air is forced through it due to suction from the induced draught pads.[1]. In fully covered greenhouses using fan and pad system of cooling, air moves through the wetted pads and water evaporates. With each gallon of evaporated water, 8,100BTUs of heat energy is absorbed from the airby the water in the process of changing from liquid to vapour. As energy is removed from air, the air temperature is reduced as it enters the greenhouse. (Bucklin, et al., 2004)

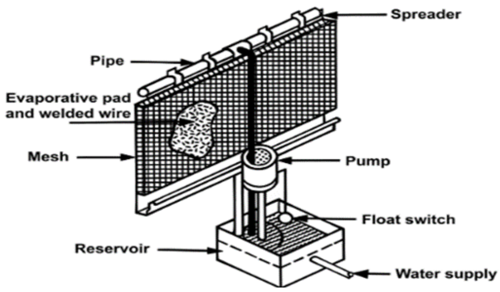


Fig. 3. A Typical Fan and Pad Evaporative Cooling System, [36].

The performance of fan and pad evaporative coolers varies between systems with different pad materials. [37] evaluated the performance of CELdek pad,cocnut noir, aspen pad and wood shavings inside a storage chamber. Air velocity, pad thickness and waterflow rate were maintained at 116m/s. 100mm and 31pm respectively for all the pads. Wood wool gave the highest temperature drop of 9.75°C followed by CELdek which gave a temperature drop of 8 °C. wood shavings and coconut noir gave temperature drops of 3.25 °C and 3.5 °C respectively. The highest maximum saturation efficiency was also from Wood wool at 92.20%, while CELdek gave 90.70%, wood shavings 65.83% and cocnut noir 67.42%. As related to the above, [38] evaluated straw pads, CELdek pads and sliced wood pads as evaporative cooling pads using three greenhouses with cuccumber plants in Khartoum, environmental parameters were measured at 8 am,1 am and 6 pm and it was observed that even though the greenhouse with straw pads had the lowest temperature followed by CELdek and then wood pads, the highest yeild, highest stem length and diameter, highest number and width of leaves, highest fruit length and diameter, highest weight of fresh and dry matter of fruit was recorded in the greenhouse with the wood pads followed by the greenhouse with CELdek pad and the greenhouse with straw pads had the least yeild and plant parameters. In the determination of the performance of Cellulose cooling pads in comparison with Aspen and Khus cooling pads, [22] developed the following equation for thermal effectiveness of evapotaive pads.

$$E = \frac{T_{out} - T_{in}}{T_{out} - T_{wb}} \quad \ldots\ldots(2)$$

Where T_{out} and T_{in} are the outlet dry bulb temperature and the inlet dry bulb temperature respectively

T_{wb} is the wet bulb temperature and
E is the Thermal Effectivenss of the pads.

They further presented the Saturation efficiency of the pads at different pad thickness as follows.

Table 1. Saturation Efficiencies of Cellulose, Aspen and Khus Evaporative Pads

Pad Material	Pad Thickness (mm)	Saturation Efficiency (%)
Cellulose Pad	150	90.37
Cellulose Pad	50	61.19
Aspen Pad	18	54.51
Aspen Pad	36	78.31
Khus Pad	20	48.62
Khus Pad	40	33.72

From Table 1, increase in evaporative pad size increased the saturation efficiency except for khus pads. In line with the observations of [37] , [39]compared the performance of evaporative pads made of cocnut noir pads, sackcloth pads,and jute fiber pads as alternative pad materials and observed that the pad made of coconut noir gave the highest maximum cooling efficiency of 85%bagainst jute fiber (78%) and sackcloth(69%). The cocnut noir pad also gave a minimum water mass flow rate of 0.25kg/sec and a maximum air velocity of 5.6ms^{-1}. Similarly, [40] discovered from an experiment conducted in six cities of Morroco(Erachidia, Marakech, Fez, Tangier and Ifrane) that the thickness of evaporative cooling pads and frontal velocity affect the performance of the fan and pad system. It was observed during the performance tests that the cooling capacity and rate of water consumed increase with increased frontal velocity and pad thickness while the coefficient of performance decreased with increasing frontal velocity and pad thickness.

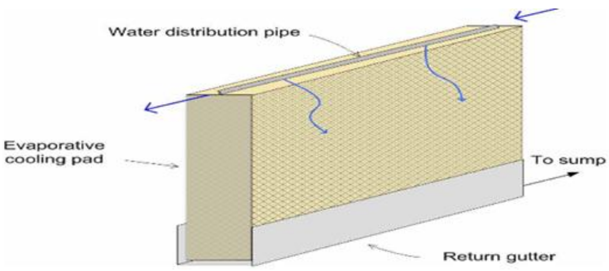


Fig. 4. Evaporative Cooling Pad, [20].

On investigating the cooling effects of a fan and pad system using an experimental greenhouse in Hangzhou, China, [41] observed that the installation height of the fan and pad cooling system affects the greenhouse cooling effect.

They observed that at crop canopy of 2-3m, optimal cooling occurred when the fans were installed at height of 0.6m – 1.4m from the ground and the pad located at a height of 1.4m.

Also at crop canopy of 1-2m, optimal cooling occurred when the fans were installed at the height of 0.6-1m or even 1.4m and pad installed at a height of 1m or 1.4m. at crop canopy of less than 1m, the fan and pad installation height at any of the settings above gave optimal cooling, [42] credited the performance or cooling efficiency of pads in the fan and pad systems to psychrometric parameters like outside temperature, pad temperature and its wet bulb temperature. They observed that the closer the pad temperature is to the wet bulb temperature, the higher the cooling efficiency of the pad. [43], attributed the cooling capacity of evaporative pads to the influence of the geometry of the pad material and the flows of water and air that pass through them. An experiment was carried out by [44], to determine the effect of air humidity on the efficiency of the greenhouse fan and pad sooling systems using a triangular roof block greenhouse covered with a single layer of glass. The fans and pads were aligned in perpendicular positions to the greenhouse end side and six temperature sensors were used to measue temperature at 12 points in the greenhouse. It wa sobserved that the fanand pad system worked efficiently in areas of low relative humidity values. At a relative humidity of 20%, internal temperature was reduced by 8^{o}C after being on for 1hr 30 mins. The efficiency of the system was also noted to be 80% on the day of the lowest humidity value.

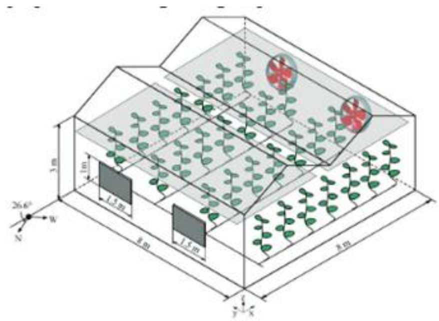


Fig 5. Schematic of experimental greenhouse(using the fan and pad cooling system) used for cooling experiments, [42].

An experiment carried out in a greenhouse at the university of Nkara, Turkey by [42], to assess the performance of the fan and pad cooling system using five temperature and humidity sensors and two pyranometers showed that the fan and pad cooling system reduced the temperature of air entering the greenhouse by 5-12^{o}C and increased the relative humidity by 25-43%.

The average air temperature inside the greenhouse was also reduced by 6.9^{o}C while the hourly mean cooling efficiecy and cooling effect of the fan and pad system were calculated as 78.8% and 6.96^{o}C respectively. Due to its reliance on low humidity conditions for optimum performance and the variations in temperature experienced in large greenhouses using the fan and pad cooling systems, recent research in the field has been focusing on augmenting the fan and pad evaporative cooling system with other cooling methods to achieve a more homogenous environment in agricultural greenhouses, [45], proposed the combination of fan and pad cooling system with thin water film applied to the grenhouse roof.

Two greenhouses, ome with fan and pad system alone and another with fan and pad system together with the roof water film were studied and compared. It was observed that the temperature in the greenhouse with the combination of fan and pad/roof water film was 1.1-5.44°C lower than the greenhouse with the fan and pad cooling system alone. After a comparative experiment between four cellulose cooling pads of varying thickness and geometry and evaporative cooling boxes conducted by [43] which revealed a higher saturation efficiency of 82.36% for the cooling boxes against the evaporative pads saturation efficiency of 65% , the use of evaporative cooling boxes was proposed over the evaporative cooling pads especially in hermetic(airtight) greenhouses.

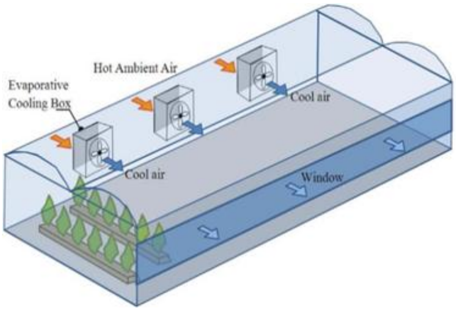


Fig. 6. Evaporative cooling boxes, [43].

Taking a different direction towards better performance of the fan and pad evaporative cooling system, [46] created a modification of the conventional fan and pad evaporative cooler which uses a granule silica gel sieve to absorb the excess moisture of ambient air before passing through the cooling pads with the aim of reducing the air moisture and consequently increasing the efficiency of evaporative cooling. They further compared the performance of this Modified Evaporative Cooling system (MECS) wth the conventional Fan and Pad Evaporative Cooling System (FPECS) and observe dthat the air leaving the evaporative pad was reduced by 30.3% by the MECS over the FPECS. The microclimate parameters observed in the MECS and FPECS greenhouses are presented below.

Table 2. The greenhouse microclimate parameters for MECS and FPECS, [46].

		MECS	FPECS
Inside Temperature (°C)	Minimum	26.3	31.4
	Maximum	31.4	35.2
	Average	29.2	33.4
Vapour Pressure Deficit (VPD) (kPa)	Minimum	0.79	0.80
	Maximum	1.77	2.00
	Average	1.39	1.50
Relative Humidity (%)	Minimum	57.2	63.7
	Maximum	76.9	82.6
	Average	65.2	71.4
Evaporative Cooling Efficiency (%)	Minimum	85.1	57.4
	Maximum	92.1	67.0
	Average	89.6	62.1
Yield Per Feddan (ton/fed)	Average	48.42	40.32

From Table 2, it is clear that the MECS provided a better microclimate for crop production.

Natural Ventilation

Ventilation methods of cooling greenhouses aims towards remoal of trapped heat from greenhouses by replacing the warm air inside the greenhouse with cold air outside the greenhouse due to the density differnece between the inside and outside air [1], [13] attributed the air exchange between the interiors and exteriors of a greenhouses through ventilation to temperature and wind effects.

Natural ventilation in greenhouses is basically the exchange between the greenhouse outside and inside air as facilitated by natural wind, differnce in air density and/or the air "buoyancy effect". Natural ventilation improves the optimal control of air temperature , humidity and gas concentration within the greenhouse thereby regulating the transpiration and photosynthetic activities of plants leading to improved crop quality.[47]. The potential for natural ventilation is highest during winter when the temperature difference between the inside and outside the greenhouse is very high however that is when the need for ventilation is least.[48]. The reliance of most greenhouses on natural ventilation makes them suitable for use in mild climates or for the production of heat-tolerant crops. [49]. . In respect to its design,[50] , suggested that greenhouses using natural ventilation as its cooling system should be designed in a way to allow warm air rise through the ridge vent as cooler air comes in along the sides. Natural ventilation according to [51] is the least expensive cooling method for greenhouse cooling thus the popularity. Lower construction and maintenance cost, supply of fresh oxygen, reduction in incidences of insect pests or disease,non-requirement of electricity, achievement of optimum temperature and relative humidity,and high suppot for pollination are amongst the many advantages of natural ventilation in agricultural greenhouses.[18]. Natural ventilation types in greenhouses are usually automatic or manually operated roll-up sides or ridge vents constructed as the main part of the greenhouse structure. [48].

[1] noted that the rate of air exchange is a very crucial factor for naturally ventilated greenhouses and depends on the total area of vents in the greenhouse as well as the wind speed and temperature difference between the inside and outside air in the greenhouse. Consequently , they advised that in naturally ventilated greenhouses, total area of vent openings should range from 15-30% of the floor area as any frther increase in vent openings will give marginal increase in performance.

Fig 7. A Naturally Ventilated Greenhouse in University of Georgia, [50].

While studying the effects of two ventilator opening angles (15^o and 45^o)jon the temperature inside a single span greenhouse (22m× 10m×4.90m) located at the University of California , Davis, [51] observed that at ventilator opening angle of 15^o and clear glass cover, t_{gh} (temperature of the greenhouse) , t_p(plant canopy temperature) and t_{gm} (growing media temperature) were reduced by 3.1°C, 9.1°C and 9.0°C respectively. At ventilator opening of 45^o the t_{gh} , t_p and t_{gm} were reduced by 7.14°C, 15.20°C and 15°C respectively. During an investigation on the effects of natural ventilation on greenhouse climate, growth and production of tomato *Solanum Lycopersicum cv* FMTT260 using two 20mby 10m greenhouses at the Asian Institute of Technology (AIT), 44km North of Bangkok, [52] noted that plants grown in naturally ventilated greenhouses had higher transpiration rates and consequently higher crop water requirements and a lower WUE(water use efficiency). On the choice of sidewalls versus roof vents, [53] tested the various roof configurations of roof vents (with the side wall vents constantly open) and observed that 64% of heat removal from the greenhouse was achieved through natural ventilation with the windward roof vent closed (which is the highest percentage of heat removal obtained). The observation was made from the airflow data from the vents of the green house under three scenarios. The data is presented below:

Table 3. Airflows through the Greenhouse windows in the anaylysed sections, [53]

Airflow (m^3/h/m)	Sidewall Vent	Windward Roof Vent	Leeward Roof Vent
Scenario AO	61.73	59.45	-77.50
Scenario WC	73.47	0	-50.62
Scenario LC	26.15	28.43	0

Scenario AO is defined as all greenhouse vents open during the time interval considered for the experiment (this is assumed to be the real operating condition of a greenhouse).

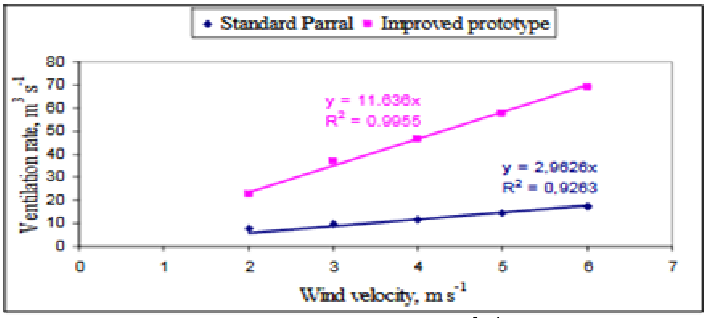
Scenario WC is defined as roof windward vent closed, side vent open and leeward vent open. Scenario LC is defined as leeward roof vent closed, side vent open and windward roofvent open

The data presented in Table 3 shows that Scenario AO has the best overall air inlet of 121.18 m^3/h/m and outlet of -77.50 m^3/h/m . this shows that a combination of wall vents and roof vents is suitable for greenhouse farming. Similarly, (Lee & Short, 2001) analysed the airflows in a naturally ventilated multi-span greenhouse with plants using a Computational Fluid Dynamics(CFD) simulation program with the $k-\varepsilon$ turbulence model and recorded an air temperature difference (between the inside and the outside of the greenhouse) of 35°C, the fourth roof vent and westside vents were predicted to be the most active outlets and inlets and the west side vent was also the only vent for west wind of 2.5ms^{-1}. The first second and third roof vents also showed CFD computed volumetric flow rate percentages as 14.2%, 7.8%,18.7% and 59.3% respectively. The CFD program predicted exit air volumetric flowrate percentages to be 37.1%, 31.0% and 31.9% for the first, second and third roof vents respectively while 2.0%, 2.9% and 95.1% were predicted for the inlet air at the same vents. Using a 2-D Computational Fluid dynamics(CFD) transient simulation of the indoor temperature and the airflow distributions in a solar greenhouse with removable backwalls, [54] observed that a backwall vent of 1.4m significantly increased the efficiency of the greenhouse.

Comparing the preicted air exchange rates for multispan greenhouses using various roof and side vents openings, (Kacira, et al., 1998) observed that the most acceptable air exchange rates were obtained when the windward side vents were combined with the leeward roof vents. The two span case gave ventilation ranges of 1.4 – 4.01A.Cmm^{-1} while the four span cases gave ventilation rate ranges of 0.14-2.0 A.Cmm^{-1} .

Greenhouses with only sidewalls are usually ventilated only during periods of outside wind movement therefore to satisfactorily ventilate a greenhouse, it must have both sidewall and ridge vents as both permit the greenhouse to be ventilated by both thermal gradients and wind pressure. [12]. Considering the effect of the direct impingement of on plants for greenhouses using sidewall vents that open from the bottomof the sidewall (to boost buoyancy effect), [55] suggested the use of deflectors with 45^{o} angle along the length of the sidewall in order to redirect the airflow towards the top of the crop allowing it to mix with the air inside the greenhouse and avoiding direct impact on the crops. Similarly, [56] conducted a study of wind-driven ventilation in greenhouse with focus on the effects of screens on the greenhouse inside airflow distribution using a finite volume CFD code (Ansys Fluent 17.2), a standard $k - \varepsilon$ turbulence model and proper user defined functions (UDF) for turbulent profiles and inlet velocity. It was observed that the cases using screens showed more uniform distribution of the velocity field inside the greenhouse than the cases without screens. This shows that screens have a strong effect on the distribution of volume flow rates through the vents and the the airflow velocity distribution inside the greenhouse. Investigations into the effects of buoyancy forces on temperature patterns in greenhouses with lower level opening in the right heated façade and upper level opening near roof top in the opposite cooled façade conducted by [57] revealed that, assyetric opening positions enhance natural ventilation and facilitate the occurrence of buoyancy induced upward cross-airflow(both for low level supply and upper level extraction) in the greenhouse. It was also observed that increasing the Rayleigh number (Ra) increases the heat transfers in the greenhouse.

He, et al., [54] observed in a study of the effects of backwall vent dimensions on a solar greenhouse using two greenhouses; one traditional solar greenhouse (TG) and a solar greenhouse with removable backwalls(RG) that when the backwall of the RG was removed, there was a notable decrease as the maximum and average temperatures were recorded to be 5.8^{o}C and 1.7^{o}C lower than that of the TG without the backwall vent. Also the wind speed in the TG increased gradually from south to north and air velocity near the back walls was zero while in the RG, the wind velocity was greater near the air vents and the air velocity followed the "V" pattern shape distribution. A Large eddy simulation(LES) model was used by [58] in investigating the effect of vegetation and greenhouse length (in the wind direction) on ventilation. It was observed that the internal resistance of the greenhouse increased with the length of the greenhouse, the resistance factor of the vegetation increased with porosity of vegetation and the driving force which is the difference between the leeward and the windward pressures of long multi-span greenhouses were observed to be lower than that of a short single-span greenhouse and ths has a lower ventilation rate. Natural ventilation method for cooling greenhouses are typically faulted for its dependence on wind velocity and as such is not suited to low wind climates. Investigating this claim, [55] developed an improved greenhouse model with 30^{o} roof slope, rolling sidewall vents that opened upwards from the floor level, double 1.9m wide roof vents, 1m deflector below the ridge of each of the extreme windward and leeward spans and two inclined(45°) deflectors on the sidewall vents and compared the dependence of ventilaton rate on wind velocity for it with that for the standard Parral type greenhouse. This comparison is presented in a graph of the ventilation rate against wind velocity for the two greenhouses as shown below:



Graph 1. Graph of simulated values of Ventilation rate (m^3s^{-1}) against Wind velocity (m^3s^{-1}) for the standard Parral type greenhouse and the improved model, [55].

From Fig 8, the R⁻ squared value for the Improved prototype also confirms that the variations in ventilation rate values appear to be caused by the variations in the wind velocity values therefore it is evident that even though the Improved prototype greenhouse model gave higher ventilation rates than the Parral type, the ventilation rate had a higher dependence on wind velocity when compared to the standard Parral type.

THE NIGERIAN PERSPECTIVE

Climate change has taken a toll on the Nigerian Agricultural system causing a threat to food security due to declining agricultural productions. [59]. The greenhouse technology was developed and introduced for cultivating horticultural crops continously in areas with unfavourable climatic conditions by providing protection from the extreme weather, [60]. The Nigerian government as well as some resourceful farmers embarked on greehnouse technology for vegetable production due to the unfavourable environmental condition, pest and disease attacks as well as climate change affecting vegetable production in Nigeria, [61]. Even though most horticultural crops can be grown in the greenhouse, greenhouses in Nigeria are majorly used for vegetable production regardless of the barely reasonable profit made from it. A profit/loss and discounted cash flow analysis of a greenhouse project in Ajayi Crowther University, Oyo Town, Nigeria, caried out by [62] recorded a N490,969.97 accrued surplus from the second year and a net present value (NPF) of +N885,339.91 through the life of the project. It was also noted that the project broke even on the sixth year. A more specific study on greenhouse vegetable production by [60], recorded the average output of tomatoes with the monetary return as 480/tonnes for each greenhouse and N1,920,000 / greenhouse , respectively.

In spite of these profits recorded by horticultural crop farmers using greenhouses for production in Nigeria, the adoption of the use of greenhouses in vegetable farming as a profitable venture is still unacceptably low.

A study by [61] in Ogun state showed that even though greenhouse vegetable farming increases yields up to 94.3% and makes available all year round supplies up to 85.7% with increased income generation of 75.7%, most farmers have difficulties in establishing greenhouses for vegetable production due to high cost of construction and the technicalities involved in establishing and managing them. The lack of technical know-how is considered the major reason vegetable greenhouses in the country with well designed cooling systems are rare as most of them rely on natural ventilation.

Many Nigerian researchers have delved into research on evaporative cooling methods and have presented scholarly articles and innovations. A good example is the development of evaporative coolers that use palmfruit fiber as cooling pad material and effects a temperature drop range of $4^{o}C$ – $13^{o}C$ at 96.8% relative humidity ambient air and provides up to 98% cooling efficiency with a 2,529W maximum cooling capacity designed by [63] which also consumes half the power of a typical vapour compression refridgerator of same volume. Study on predicted percentage dissatisfied (PDP) model evaluation of evaporative coolng potentials of some selected cities in Nigeria was also performed by [64]. The significance of active evaporative cooling systems in the shelf life enhancement of vegetable (red and green tomatoes) for minimizing post harvest losses have been studied by [65] and the performance evaluation of a composite paddled evaporative cooling storage bin by [66] are a few out of many local research on evaporative cooling systems. However, none of these research has been extended to the use of evaporative cooling system or any other cooling system in greenhouse farming.

A publication by [67] for GRAIN Nigeria, listed companies like Dizengoff Nigeria Limited, Sedfort Nigeria Limited, Saro Agrosciences Nigeria Limited and Jubarile AgroTech Limited as the key marketers of imported greenhouses in Nigeria with Sedfort Nigeria Limited being the only company among them importing fully automated greenhouses that offer climate control options to support any type of crop. The publication also noted that companies that fabricate greenhouses locally like Asher Ventures and Specialties Limited sell wooden and galvanised greenhouses at N750,000 and N1.3 million, respectively. An amount considered highly exurbitant to the average Nigerian farmer.

The average Nigerian farmer is evidently more concerned about the limitations to running a greenhouse crop production plant, statistically measured by [60] as 90% lack of technical know-how, 96.2% high construction cost and 83.4% poor market circulation due to low quantities produced, to bother with cooling systems for the greenhouse. Regardless of the fact that the use of greenhouses in Nigeria,have been limited to research and tertiary intitutes where they are used for academic and general researches, [68] there is little or no use of well established cooling systems for these greenhouses.

CONCLUSION

Green house cooling has widened the possibilities of ‘cold climate’ crop production in arid and semi arid climates.

In Nigeria for example, vegetables like Carrots, cabbage, lettuce predominantly grown in the northern part of the country can be succesfully raised in other parts of the country with properly cooled greenhouses to simulate the climatic environment obtainable in the north.

Fog cooling and evaporative cooling systems as reviewed in the work are the most popular types of direct evaporative cooling systems used in greenhouses and even with limitations like nozzle cloggings, variations in temperature and low performance in areas with low humidity values, they still lower temperatures inside greenhouses effectively. Although fog cooling has been discovered to be more water conservative and reduces relative humidity in greenhouses more than the fan and pad system in most cases [15], a fan and pad cooling system in an experiment by [69] was observed to lower the temperature of the experimental greenhouse more than the fog ccoling system. However, the constraints of both evaporative cooling systems can be adressed by augmenting with other greenhouse cooling systems like the natural ventilation system, evaporative box cooling system or the induced fan system.

The natural ventilation method of cooling proffers an inexpensive , simple and natural method for greenhouse cooling. Its efficiency borders on vent arrangements, vent locations, opening angles and wind velocity. However , its dependence on wind velocity hampers its versatility. Due to the dependence of the performance of natural ventilation method of greenhouse cooling on wind velocity, [50] suggested that additional cooling (e.g fog system or fan and pad system) can be used to augment the natural ventilation method in maintaining the greenhouse microclimate. An example is the Natural Ventilation Augmented Cooling (NVAC) system used by [49], which comprises of a natural ventilation system augmented with a misting system.

This NVAC system succesfully lowered the greenhouse temperature by 1.3-3.6^{o}C and increased the relative humidity by 5.7-17.7% compared to the outside environmental conditions.

In Nigeria, greenhouse cooling is still limited to natural ventilation. After scaling through the costs of construction, operating and managing the greenhouse, the averge Nigerian farmer has no budget for a properly designed cooling system to complement the greenhouse farm. This hampers large scale food production especially in off seasons and for a country losing the war on food insecurity , government intervention is crucial.

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PREGLED ZAJEDNIČKIH SISTEMA PRIRODNE VENTILACIJE I HLAĐENJA ISPARAVANJEM ZA STAKLENIKE I REALNOST NIGERIJE

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Sažetak: Staklenici simuliraju potrebno o ru e n e a uspe an rast i ra vo bil a a. n i di a nom posti u ova vo o ru e n e isporu u u i neophodne limats e inpute potrebne bil ama, i istovremeno is l u u u fa tore o i ometa u rast bil a a, pa se zato nazivaju i objekti sa ontrolisanim o ru e n em. edno od na e ih i na potrebnijih karakteristika staklenika je njegova sposobnost da obezbede efi asno hlađen e bil a a. v a rad e op irno analizirao oncept hlađen a isparavanjem koji se primenjuje u staklenicima.

Ta ođe su ra matrani fa tori: deficit pritiska pare (VPD), relativna vla nost i temperatura okoline, obzirom na efekte efikasnosti sistema hlađen a isparavan em.

Analizirana je efikasnost sistema ventilator-sistem a evaporativno hlađen e (evaporator) i sistema a maglu i upoređena sa n ihovom posledi n om avisno u od fa tora ao to su: ra ma mla nice, du in a mla nice, efi asnost a si en a materijala (ulo a a) sistema za evaporativno hlađen e, itd. Metoda prirodne ventilaci e ta ođe e analizirana za poseban staklenik i na in hlađen a, ao dodata ostalim sistemima a hlađen e.

Analizirani su faktori poput brzine razmene vazduha u objektu, u upne povr ine ventilacionih otvora, brzine strujanja vazduha, uglova otvaranja otvora itd, a razmatrani su u s ladu sa n ihovim efe tima na efi asnost metode prirodne ventilaci e. Ta ođe e predstavljena perspektiva staklenika u Nigeriji i njihova metoda hlađen a, sa osvrtom na razvoj lo alnih sistema a evaporativno hlađen e (ispariva i hladn aci) kao i na mogu n ost a n ihov uvo , pristupa nost, ori e n e-upravljanje, dostupnost i primenu za poljoprivredne kulture u Nigeriji.

Ključne reči: *temperatura okoline, hlađenje isparavanjem, hlađenje ventilatorom i evaporatorom, hlađenje maglom, staklenik, relativna vlažnost.*

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A REVIEW OF BIOREREMEDIATION OF HYDROCARBON CONTAMINATED SOILS IN NIGER DELTA AREA OF NIGERIA

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Abstract: Bioremediation technologies are an environmentally friendly approach for the treatment of polluted soils. This review take a look at the various remediation efforts by various scientist to ameliorate the effect of crude oil contamination on the environment. Contamination of the total environment (air, soil, water and biota) by crude oil has become a paramount interest in the Niger Delta region of Nigeria. With the frequent reports of oil spillages in the Niger Delta area, there is need to seek for a cost effective method for remediation of crude oil impacted soils. Studies have revealed variable impacts of oil toxicity on the environment and exposed populations. Soil contamination is caused mainly by the leakage of underground storage tanks and pipes. The most common conventional method for the remediation of contaminated soils is excavation followed by landfilling or incineration and other technologies that have been widely practiced. Contaminated sites pose a threat to human life due to severe health problems caused by adverse health effects from exposure to soil contamination. Once it is being detected, assessment strategies, type of sampling, chemical analyses, evaluation of parameters and its effect must be done. Several technologies and parameters have been developed to treat petroleum hydrocarbon contaminated soil but the problem still exists.

***Key words**: Petroleum hydrocarbons, Natural attenuation, Bioaugmentation, Phytoremediation, Biopiles.*

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INTRODUCTION

Persistent release of petroleum hydrocarbons, toxic chemicals, and industrial waste have a detrimental impact on human health and environment. Oil contaminated soil in and around exploration and spillage areas are still a major environmental problem. The effect of oil spill has been frequently felt in the Niger Delta region of Nigeria. It is reported that the agricultural land near the oil exploration sites are often contaminated by hydrocarbons and land become unfit for agricultural cultivation [1]. Hydrocarbon contamination of the environment generally occur due to exploration, processing, and transportation of refine and unrefined product from one location to another. However, historic and ongoing human activities have resulted in large-scale contamination of lands, and in worst case scenario hitherto useful lands are transformed to wasteland [2]. Contamination of soils with petroleum hydrocarbons is one of the attendant environmental problems associated with industrialization and the dependence on petroleum and its by-products. One of the major agencies that have caused habitat destruction and modification i.e. ecosystem alterations is industrialization and technology, through air, water, and land pollution.

Soil contamination with petroleum hydrocarbons can be defined as any earthen material or artificial fill that has human or natural alteration of its physical, chemical, biological or radiological integrity resulting from the introduction of crude oil, any fraction, or derivative thereof (such as gasoline, diesel or motor oil, or oil base product [3,4]. The natural environment may be altered or even exterminated by man through series of agencies and effects. In the petroleum industry for example, pollution of the environment may occur through effluent discharges and accidental oil spillages. Studies indicate that subtle changes occur in the Nigeria aquatic and terestrial ecosystems due to the activities of the oil industries [5]. These studies in Nigeria reveals that the development and production processes in the oil and gas industries require an urgent need to plan, protect, and prudently ultilize environmental resources for a better environment for man. Most of the environmental changes occur from the release of crude oil into the environment. Thus, considerable attention has been paid to develop suitable techniques for effective remediation [6,7]. Over the last three decades, extensive studies have been conducted using different technologies including coagulation and flucculation, phytoremediation, reverse and forward osmosis, chemical oxidation, photocatalytic degradation and adsorption, [8,9,10].

MATERIAL AND METHODS

1. Soil Contamination

Soil contamination is a global problem that constitutes significant threat to human and environmental health both in the present and in the future. Soil contamination has been an important topic in many areas of research, practice and policy within different countries which has also been extended internationally, [11]. The attached importance to contaminated soil has been increasing over the years. Increased population growth and industrialization around the world are key factors responsible for the increase in the contamination of soil and the environment which negatively affects various human health, wildlife, and microorganisms.

The contaminant sources are waste disposal sites, mining sites, crude oil refineries and exploration, chemical application in agriculture, use of wastes water for irrigation, industrial emissions and maintenance, [12]

Contaminant can be any element that has the potential of causing harm on the environment. Environmental contamination is primarily interested in the physical, chemical or biological agents or their combinations that may pose a threat to life, health, safety or welfare of organisms in the environment. Soil contamination is the existence of these contamination above permissible limits at which deterioration or loss of soil functions occur, [13]. Major areas of soil contamination and pollution have been highlighted by [14] as follows:

I. Radioactive pollution of the soil. Accidental release of radioactive substances has been discovered in some part of the world. The substances are very harmful to the soil and provide an unsafe environment for human life and living organisms. There is currently serious concern over the risk of soil pollution on food safety and the sustainability of agricultural production across the globe. Fears of the food chain being compromised by soil pollutants are eminent as the consumption of food crops contained with pollutants remained a major suspect in food poison. Several studies have linked serious human health challenges to heavy metal accumulation by plants from contaminated soils, [15,16,17,18]

II. Soil acidification through the accumulation of acid from phosphate fertilizer, carbon, nitrogen and Sulphur cycles, and acid rains. Soil acidification lowers the soil pH and alters the soil chemistry. When the soil pH is reduced, the bioavailability of heavy metals in the soil is increased and a harmful environment for biological activities is created, the breakdown of nutrients for plant uptake is also hindered and the food chain compromised.

III. Direct introduction of toxic elements and compounds such as petroleum hydrocarbon and other dangerous organic compounds. This contributes to making the soil unsafe and creates an impediment in its functions.

2. Soil Contamination by Petroleum hydrocarbons

The word petroleum means rock oil or oil from the earth. Petroleum hydrocarbon is a term used to describe a large family of several hundred chemical compounds that originally come from crude oil. This mixture of chemicals can be described by common chemical characteristics such as boiling point ranges or size of the molecules. Petroleum hydrocarbon is a complex substance formed from hydrogen and carbon molecules and sometimes containing other impurities such as oxygen, Sulphur, and nitrogen, heavy metals and oxygen compounds. Examples of petroleum hydrocarbon contaminants are total petroleum hydrocarbons (TPHs) and polycyclic aromatic hydrocarbons (PAHs). Soil contamination with petroleum hydrocarbons is one of the adverse environmental problems associated with crude oil exploration in any part of the globe. Natural gas, Crude oil, tars and asphalt are types of petroleum hydrocarbons, [19].

Total petroleum hydrocarbons (TPHs) are used to describe mixture of organic compounds found in or derived from crude oil that has the potential to be very toxic (CCME, 2001). Total petroleum hydrocarbons can generally be divided into three fractions: (i) aliphatic, (ii) aromatics and (iii) polar and asphaltenes [20]. When soil is contaminated by petroleum hydrocarbons, the soil will have insufficient aeration due to the displacement of air from the spaces or pores between the soil particles. The displacement of air in the soil pores by petroleum hydrocarbons will cause anaerobic environment in soil by smothering soil particles and blocking air diffusion in the soil pores and affect the soil microbial communities negatively [21,22,23].

Figure 1. Crude-oil contamination in the Niger Delta area of Nigeria

Most product that contain total petroleum hydrocarbons (TPHs) are naturally volatile. Some are clear or light colour liquids that evaporate easily and others, are thick, dark liquids or semi-solid that do not evaporate and many of these products (gasoline, kerosene, etc.) have oily odours, [24]. The composition of petroleum hydrocarbons (PHCs); varies slightly by its source, but the toxic properties are consistent. Chemicals such as benzene and polycyclic aromatic hydrocarbons (PAHs) are extremely toxic components of serious concern [25]. Table 1 shows the percentage of elements and hydrocarbon contaminants present in crude oil.

Table 1. Percentage of elements and hydrocarbons present in the crude oil, [26].

Major components of crude oil		Hydrocarbons present in crude oil		
Element	Weight (%)	Hydrocarbons	Weight (%)	Range
Carbon	84-87	Alkanes (Paraffins)	30	15-60
Hydrogen	11-14	Naphthenes	49	30-60
Nitrogen	0.1-2.0	Aromatics	15	3-30
Oxygen	0.1-2.0			
Sulfur	0.06-2.0	Asphaltic	6	Remainder

3. Soil Remediation

Soil remediation is any operation that can reduce the concentration of the contaminant, through chemical, biological or physical means in order to reduce the amount, and the mobility of the contaminant to an acceptable permissible concentration. The remediation of contaminated soils has become a serious concern and has created huge challenges globally in recent years.

Although environmentalists, engineers, and various stakeholders have made considerable efforts to deal with the remediation issues, the problem has persisted. This may be likely, due to population increase. Remediation of contaminated soils is targeted at reducing the risk associated with pollutant and improving the quality of the environment while complying with regulatory requirements.

Various methods and technology have been proposed by many researchers and government agency, [27,28,29]. Existing publications have indicated that the major degradation of TPH occurs in the aliphatic fraction, [30]. The aromatic fraction appears to be reduced with relatively low efficiency, and the polar and asphaltene fraction frequently accumulates in the later stage of degradation, [31,30].

4. Bioremediation

Bioremediation is a process that allows the remediation of harmful/toxic chemicals by natural processes [29]. It exploits the metabolic diversity and adaptation of microbes for degrading and transforming various organic and inorganic contaminants [32]. For practical application of bioremediation to be considered, there should be a demonstration that the removal of contaminants is the primary effect of bioremediation and that the degradation rate is greater than the natural rate of decontamination [33]. For practical application of bioremediation to be considered, there should be a demonstration that the removal of contaminants is the primary effect of biodegradation and that the degradation rate is greater than the natural rate of decontamination [33]. Since microbes existing in soils/groundwater feed on certain chemicals, the complete digestion of this chemicals by microbes convert them into water and gases such as CO_2 [34]. Commonly used organisms for this purpose are bacteria, fungi or protozoa either natural occurring or genetically modified, [35]. Organisms have been widely studied and shown to destroy organic chemicals, whereas they can either remove or convert to stable form. For bioremediation to be successful, it is important to ensure that the correct environmental conditions are in place to maximize the growth and activity of the microbes. These conditions include nutrient content, soil structure and texture, temperature and oxygen content as well as the correct assemblage of the microorganisms, [36]. If these conditions are not met, the microbes could grow too slowly, die or even create more harmful chemicals, [37]. Different kinds of bioremediation methods have been developed to reduce the time required for degradation and reduce cost by increasing the derivative activity of native microbial populations, [38]. These approaches include the following which can be in-situ or ex-situ.

5. Biostimulation

Biostimulation involves the addition of oxygen or mineral nutrients to stimulate the numbers and activities of natural populations, usually bacteria and fungi so that they can break down pollutants into harmless products, [38]. In most environments, the presence of nitrogen and phosphorous is limited, even when total concentrations are high, it may be in a mineral form that is biologically unavailable, [39].

Therefore, Biostimulation accelerates the decontamination rate as the addition of one or more rate limiting nutrients improves the microbes degrading potential, [40].

Nitrogen and phosphorous has been widely used in Biostimulating processes to support growth of microorganisms, [41] showed that the addition of nitrogen and phosphorous as inorganic fertilizer and the addition of biosolids enhanced the biodegradation of petroleum hydrocarbon by up to 96%.

However in some cases, addition of nutrients can negetively affect the microoganisms and biodegradation is suppressed. [42] showed that phenanthrene mineralization rates were depressed or remained the same with the addition of nitrogen and phosphorous to phenanthrene-contaminated soil.

This could be as a result unbalanced or inapropriate level of nutrients, adsorption of the pollutant to the medium (soil) that prevents the availability of the pollutants for destruction or inactivity of the indigenous microbes caused by high concentration of pollutants.

6. Bioaugumentation

The success of bioremediation usually requires the application of strategies that are specific to the particular environmental conditions of the contaminated sites. Bioaugumentation which includes the addition of pre-adapted consortium, introduction of genetically engineered bacteria or the addition of biodegradation relevant genes packaged in a vector to be transferred b conjugation into indigenous microorganisms plays a major role during biodegradation [43]. From an application perspective, using microbial consortiouminstead of a pure culture for bioaugumentation ia advantageous [44]. Two factors limit the use of added microbial pure cultures for contaminated land treatment. Firstly, the non-indigeneous cultures are unable to compete properly with the indigenous population to develop useful population level and secondly, most soils that have been exposed to biodegradable contaminants for a long period have indigenous microorganisms that can effectively degrade the contaminant if treatment is properly managed [45]. Although this method of remediation is simple, there have been many records of failures. [46] showed that there was no improvement on nitrogen removal when a nitrifying batch reactor was inoculated two times with areobic dentrifying bacteria even after addition of acetate as a nutrient. Nevertheless, some work has shown promise for the strategy of combining both bioaugumentation and biostimulation to enhance bioremediation [43]. [47] successfully obtained complete degradation of diesel oil and phenanthrene to an overall 75% reduction of the total hydrocarbon in 42 days. Indigeneous and exogenous microbes could benefit from the addition of energy sources or electron-acceptors.

[48] with their development of a combined bioaugumentation and biostimulation process for treatment of site highly contaminated with atrazine, showed that bioaugmentation with *Pseudomonas sp* strain ADP and citrate or succinate biostimulation increased atrazine mineralisation.

7. Composting

This method is based on ancient method of turning household waste into usable organic amendments. It useds the biological system of microbes in the compost to breakdown or transform contaminants in soil/water [49]. This method of remediation has received little attention even though it has been used for treatment of contaminated soils for many years [50].

Most of the work has been carried out on low levels of contamination although compost has shown potential for remediation of heavily contaminated sites [51].

Many contaminants like Petroleum Aromatic Hydrocarbons (PAH) [52], heavy metal [53] and pesticides [54] have been remediated by this method. [52] showed that after 42 days of composting, 35 to 68 % of both 3 to 4 rings and other higher molecular mass PAH were removed.

Metallic contaminants are not degradable, therefore during composting, they are converted into organic combinations that are less bioavailable than the mineral combination of the metals [53]. [55] showed that during composting of biosolids and municipal wastes, there was a decline in soluble components of metal like Zinc (Zn), Chromium (Cr), Copper (Cu) and an increase in residual, organically bound forms. Compost remediation works in the same way as the biological process of soil remediation. As there is increased temperature in compost than in soil, there is increased solubility of contaminants in compost than in soil, there is increased solubility of contaminants in compost which increase destruction of contaminants helped with an increase and diversity of microbial population [53]. Microbes play an important role from the beginning to the end of composting. Their increase and diversity are controlled by changes in levels of moisture, temperature and nutrients, these ensure that the contaminants are exposed to a wider range microbe-environment conditions [56]. Although composting has been effective [57], its vulnerability to high concentration (>2500 ppm) of heavy metal (microbial growth could be inhibited), its requirement for impermeable liners and its requirement for large area of land for treatment has limited its use [58].

8. **Land Farming**

This is an ex-situ remediation method that involves the application of contaminates soil to the land surface and with periodic mixing with agricultural equipment contaminant biodegradation is achieved [59]. Contaminants such as total petroleum hydrocarbon (TPH) can also be volatilized using this process [60]. Tilling of the soil periodically disrupts the aggregate, which accelerates nutrient and contaminant distribution throughout the soil while providing oxygen to the soil [59]. As microbes in soil have diverse catabolic activities, adding compounds containing microbes to the contaminated sites leads to pollutant degradation [61]. Cover crops could be planted during land farming remediation. This would enhance rhizosphere degradation [54]. Land farming is slow because the conditions that affect degradation such as temperature and rainfall are uncontrolled [62], it is low cost technology. The rate of application is calculated and the size of land is based on the application rate. This is done to avoid concentrations that would be detrimental to the soil [63]. Most land farming remediation reqiures the addition of nutrients to accelerates degradation by indigenous microbes. With the addition of fertilizer, biodegradation was enhanced and enough hydrocarbons were degraded when land farminf was applied on hydrocarbon contaminated soil in the Canadian Arctic [60]. Although land farming is an effective remediation technique, it has its shortfalls. These include its remediation potential for inorganic since they are non-biodegradable and the presence of haevy metal concentration of 2500 mg/kg or more may inhibit microbial growth. Volatile constituents may evaporate during aeration and could cause air pollution and its requires large land area for treatment.

Dust generated could cause air pollution and it is difficult to achieve more than 90 % contaminant reduction [62].

The process of reducing the petroleum constituents present in the soil by spreading the soils on the ground and stimulating aerobic microbial activity within the soils through aeration and/or the addition of nutrients, minerals, and water/moisture known as land farming is only effective in remediating lighter petroleum hydrocarbons [64,65] as heavier hydrocarbon do not evaporate or microbially degrade through this process [64].

9. Biopiles

Biopiles is another commonly used treatment process for hydrocarbon contaminated soil. It is a method that involves the piling of petroleum-contaminated soils into piles or heaps and then simulating aerobic microbial activity by aeration and the addition of minerals, nutrients, and moisture [66]. The bio-piled soils are often subjected to heat and pH alteration to enhance biodegradation [64]. This method is similar to land farming, but in the latter, the soil is aerated through tilling and ploughing [66]. This treatment option is only effective in reducing light fractions of petroleum hydrocarbon in the soil, and does not also lead to complete removal or degradation of hydrocarbon from the soil [64].

10. Phytoremediation

Phytoremediation is a treatment method that uses plants to clean up hydrocarbon and other contaminants from the soil. The process takes advantage of the ability of some plants to take up, accumulate, and/or degrade constituents that are present in soil or process them for physiological processes [64,67]. Phytoremediation is a broad term that incorporates all the different processes that plant use to remove, transform or stabilize pollutants in soil, water or atmosphere. It is a plant-based remediation technology that is applied to both inorganic and organic contaminants in soil, water and sediments globally [68]. Naturally processes by which plants and their associated microbes degrade and/or sequester inorganic and organic pollutants are incorporated in this technology which makes it a cheaper and environmentally sustainable option to mechanical and chemical methods of removing contaminants from soil [68]. It also generates fewer secondary waste and less environmental impact than would be obtained using other traditional methods [69]. Results of research for phytoremediation potential show that it is applicable to a broad range of contaminants including metals [70], radionuclides [71], organic compounds for example, chlorinated solvents, BTEX (benzene, toluene, ethyl-benzene and xylene) [72], polychlorinated biphenyl [73], polycyclic aromatic hydrocarbons (PAHs) [74] and pesticides [73].

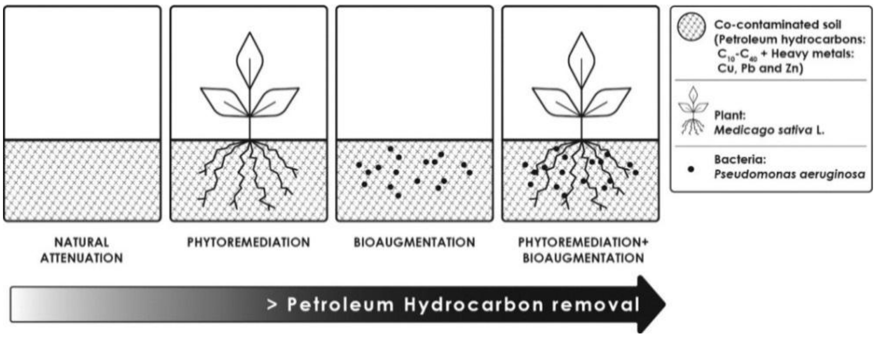

Figure 2. Different methods of petroleum hydrocarbon removal from contaminated soil, [75].

The term phytoremediation was not used until the 1980s although the use of plants to remediate radionuclide-contaminated soils was explored in the 1950s [76]. According to [77], numerous laboratory and greenhouse studies are carried out to determine plant toxicities and contaminant uptake abilities. In order for phytoremediation to achieve global acceptance as a remedial method, field scale applications need to be carried out and documented. There have been extensive studies on application of constructed wetlands and vegetative covers in the field to demonstrate their phytoremediation capabilities as well as field scale studies of the use of plants for ground water and soil remediation [78]. This process is time consuming, as the remediation may require more than one growing season; and the treatment is limited to soils less than one meter from the surface [79]. Table 2 showed the bioremediation of petroleum hydrocarbon by different researchers in the last two decades.

RESULTS AND DISCUSSION

Table 2. Relevant studies on crude-oil related contaminants remediation in Nigeria

Ser. No.	Material use for remediation	Remediation type	Contaminants	Result
1.	Earthworms (Eudrillus euginae and Lumbricus terrestris)	Vermiremediation	Crude Oil	Activities of E. euginae led to 88.50% TPH loss, L. terrestris led to 76.42% loss while combined activities of the two earthworms led to 73.06% loss of TPH from the soil contaminated with 3ml crude oil after 30days.
2.	Corn and Elephant grass	Phytoremediation	Petroleum-Hydrocarbon	The results of the analyses revealed average hydrocarbon losses of 77.5% (Z. mays) and 83% (P. purpureum) within the first two weeks, these values decreased to 67.5% and 55% after the six-week remediation period for corn and elephant grass respectively.

				On the other hand, the corn plus elephant grass treatment showed hydrocarbon losses of 62% and 74% for the two and six-week period respectively.
3.	Goat droppings and NPK fertilizer	Biological and chemical	Petroleum-Hydrocarbon	It was observed that the application of goat droppings was able to ameliorate the levels of total hydrocarbons form 7568mg/g to 439mg/kg as against 500mg/kg produced by NPK fertilizer which indicates a better remediation in goat dropping application.
4	Fertilizer and oxygen exposure	Chemical and Oxygen	Crude-Oil	The hydrocarbon losses (50–95%) experienced in the five treatment-cells revealed the effectiveness in degrading the hydrocarbon contaminant. The results of this study indicate that the application of increased concentrations of nutrients (by the application of fertilizers) lead to greater rates of biodegradation of petroleum-polluted agricultural soils.
5	Cladosporium spp	Bioremediation	Hydrocarbon	The Total hydrocarbon concentration decreased for both the sterilized and non-sterilized sample after bioremediation. Decrease in concentration from 1.87-1.41 mg/l and 1.87-0.70 mg/l for sterilized and unsterilized samples respectively. It could also be depicted from this work that Cladosporium functions more effectively in the presence of other microorganisms since it has more effect in non-sterilized sample than the sterilized sample as clearly shown in the percentage removal (56.00%).
6.	Cyperus odoratus, Colocasia esculenta, Phoenix roebelenii and Eisenia fetida	Phytoremediation and Vermiremediation	Total Petroleum Hydrocarbon in contaminated surface water	At week 5, TPHs phytoremediation's in the monoculture reactors removal efficiency was (31.28 mg/L) 99.97% and mixed culture indicated (19.72 mg/L) 99.98%; while polyculture indicated (8.91 mg/L) 99.99%.

				The combination of phytoremediation and vermiremediation techniques in polyculture reactors showed better and spectacular results as the biotas demonstrated good potentiality of hyperbioaccumulation to serve as hydrocarbon sinks from the ecotoxics of total petroleum hydrocarbons.
7.	Sheep waste compost and goat waste compost	Bioremediation	Crude oil	The results showed that all bioremediation agents applied enhanced the natural bioremediation of the contaminated soil and the most preferred results were obtained when treatments were done using sheep waste compost. This study revealed that the remediation process was influenced by application period, type of oil, and compost rate.
8.	Moringa Oleifera leave extract	Bioremediation	Crude oil	The application of Moringa leave extract was found to be useful in the enhancing of crude oil polluted lands, and by so doing it facilitates the rehabilitation of the contaminated soil as well as reinstating the soil constituents for agricultural purposes
9.	Goat manure, poultry droppings and cow dung	Bioremediation	Crude Oil	The results of this study indicated that nutrient amendment can enhance the rate of biodegradation of crude oil polluted soil.
10	Mineral fertilizers and periodic application of different amounts of water	Bioremediation	Petroleum hydrocarbon	Laboratory analysis of soil characteristics showed an increase in the total heterotrophic bacterial (THB) counts and a corresponding reduction in soil organic carbon and total hydrocarbon content (THC) at the endof the six-week remediation period.

				The percentage of THC reduction ranged from 44% to 90% in the five treatment cells
11.	Enhance natural attenuation (RENA)	Bioremediation	Crude oil	The gas-chromatography-flame ionization detector (GC-FID) results showed that the pollutant concentrations (TPH and PAH) reduced by 98 and 85%, respectively, after the remediation.

CONCLUSION

The natural environment may be altered or even exterminated by man through a series of agencies and effects. One of the major agencies that have caused habitat destruction and modification i.e. ecosystem alterations is industrialization and technology, through air, water, and land pollution. In the petroleum industry for example, pollution of the environment may occur through effluent discharges and accidental oil spillages. Environmental studies in Nigerian reveal that the development and production processes in the oil industry require an urgent need to plan, protect, and prudently utilize environmental resources for a better environment for man. Applying earthworms to a contaminated site might be an environmentally friendly way to remove hydrocarbons from soil. However, a limitation might be the cost of the large amounts of earthworms required to remove PAHs from soil and the necessity to supply them with sufficient substrate while maintaining the water content of the soil high enough for their normal functioning.

This review indicate that subtle changes occur in the Nigeria aquatic and terrestrial ecosystems due to the activities of the oil industry.

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PREGLED BIOREREMEDIJACIJE KONTAMINIRANIH HIDROMORFNIH ZEMLJIŠTA U PODRUČJU DELTE REKE NIGER U NIGERIJI

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Sažetak: Tehnologije bioremedijacije su ekološki pristup za tretman zagađenih zemljišta. U ovom radu se razmatraju mnogobrojni napori i metode za sanaciju od različitih naučnika za poboljšanje ili popravku negativnih uticaja zagađenja životne sredine sirovom naftom.
Kontaminacija celokupne životne sredine (vazduh, zemljišta, vode i biosfera) sirovom naftom postala je najvažniji interes u delti reke Niger (ukupna dužina reke je 4184 km). Uz česte izveštaje o izlivanju nafte na području delte reke Niger, potrebno je potražiti isplativ metod za sanaciju zemljišta pogođenih izlivanjem sirove nafte. Studije su otkrile promenljive uticaje toksičnosti nafte na životnu sredinu i populaciju. Zagađenje zemljišta uzrokovano je uglavnom nekontrolisanom pojavom curenja nafte iz ukopanih podzemnih rezervoara i cevi.
Najčešći konvencionalni metod za sanaciju kontaminiranog zemljišta je uklanjanje-iskop delova zagađenih zemljšta sa formiranjem deponija, ili spaljivanje zagađenih delova, i druge tehnologije koje su široko primenljive.

Kontaminirana mesta predstavljaju pretnju za život ljudi zbog ozbiljnih zdravstvenih problema prouzrokovanih nepovoljnim zdravstvenim efektima izlaganja zagađenju zemljišta. Jednom kada se zagađenje otkrije, moraju se izvršiti: strategije procene, odrediti vrstu i način uzorkovanja, hemijske analize, procena parametara zagađenja i njihov efekat.

Nekoliko tehnologija i parametara je razvijeno za ispitivanje zemljišta zagađenog derivatima nafte (ugljovodonici), ali ovaj problem i dalje postoji.

Ključne reči: *ugljovodonici iz nafte, prirodno slabljenje, bioaugmentacija, fitoremedijacija, Biopiles tehnologija.*

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DETERMINATION OF MAIN PARAMETERS OF ISOBUS SYSTEM BASED AGRICULTURAL MACHINERY MANAGEMENT

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Abstract. ISO organization (https://www.iso.org) in early 90s defined an industry standard for the communication protocol among electronic devices of different manufacturers of agricultural machines. After that, all of the market actors recognised that this technology would be very important for agricultural electronics. The appearance of ISOBUS products in the market was in the mid-2000s. ISOBUS description could be found in ISO-11783 (https://www.iso.org).
Through the standards and the related technical background, the production processes and the operations could be followed and monitored by the extensive Data Management. Farmers' and users legitimate needs and developing goal is to elaborate a decision support systems that follow-up the utilisation of the machines and ensure the quality of operations. For this purpose, it is essential to determine which technical, economical, technological parameters detection, measurement, transmission, processing, and evaluation becomes necessary.
In our work, we reviewed which mechanical characteristic, settings are monitored within the ISOBUS system by the major machine manufacturers. We developed the system of parameters and derived features that provide effective farm-, and land-management in case of attached equipment for spreading of input materials, plant protection and tillage implements.

Keywords: *ISOBUS, data management, machinery management, agricultural mechanisation, product development*

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INTRODUCTION

1.1. ISO11783 standard and the foundation of the AEF

After almost 20 years of application and development the ISOBUS (as defined in the standard ISO11783) has become a key element in the design of modern agricultural machinery, [4, 11, 13, 15]

There is a lot of factors which prevent a smooth and fast introduction of the ISOBUS products in the market:

- the complexity of the standard;
- the rapid evolution of digital technology;
- the lifecycle of components of agricultural tractors and related return of investments;

The first two items mainly drove the creation of an industry consortium called AEF (Agricultural Electronics Foundation). This allowed manufacturers to create a common interpretation of the standard when applied to real products, [7]

Agricultural Industry Electronics Foundation, the AEF, was founded in October 2008 in Frankfurt at the VDMA. The founding members were 7 equipment manufacturers (John Deere, Grimme, Pöttinger, CNH, AGCO, Claas, Kverneland) and 2 associations (VDMA and AEM). AEF's aim was and is to provide resources and know-how for the increased use of electronics and electrical systems in mobile Farming Equipment. In the first years of its existence, it was clear that a succession of important tasks associated with ISO 11783 (ISOBUS) formed the main focus of AEF's work, [10, 11, 15]

Since its founding in 2008, the AEF has grown to a mature and independent Industry Foundation with over 200 members, [1].

ISO 11783 is a complex and large electronics protocol standard based on CAN and SAE-J1939 standards, extended for the Agricultural Industry. The standard consists of 14 different parts and more than thousands of specification pages, [5, 14, 15]

1.2. ISOBUS Functionalities

For increased transparency towards the end-customers as well as to developers, the AEF has defined the so-called ISOBUS Functionalities that are now also the basis for the certification of ISOBUS products. The Functionalities encapsulate the different Control Functions on the ISOBUS network, such as the Terminal, the Tractor ECU, an Auxiliary device or a Task Controller, [10, 14]

After a first period in which all the ISOBus sections release levels were defined in a certain ISO11783 implementation level it become evident that a more practical approach was needed to address the increasingly complexity. Eight main functionalities, each of them with its set of ISO11783 sections release, were then released by AEF, covering the main functional aspects addressed by the standard (Figure 1).

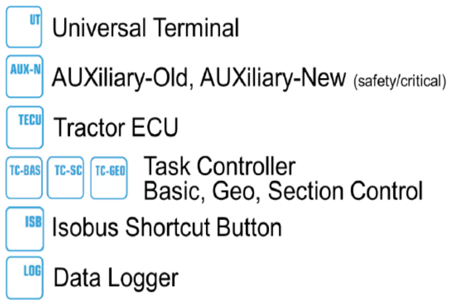

Figure 1. Today ISOBUS released functionalities, [7].

The AEF has released the following Functionalities that can be certified today by the Conformance Test:

- UT – Universal Terminal. The capability of operating an implement with any terminal. The capability of using one terminal for operating different implements.
- AUX – Auxiliary Control. Additional control elements, such as a joystick, that facilitate the operation of complex equipment.
- TC-BAS – Task Controller - Basic. Describes the documentation of total values that are relevant for the work performed. The implement provides the values. For the exchange of data between farm management system and Task Controller the ISO-XML data format is used.
- TC-GEO – Task Controller - GEO-based. Additional capability of acquiring location based data – or planning of location-based jobs, as for example by means of variable rate application maps.
- TS-SC – Task Controller - Section Control. Automatic switching of sections, as with a sprayer or seeder, based on GPS position and desired degree of overlap.
- TECU – Tractor ECU. The tractor ECU is the tractor‘s interface to the ISOBUS. This provides information, such as speed, power take-off RPM, etc on the ISOBUS for use by the implement.
- ISB – ISOBUS Shortcut Button. A button present on a Terminal, or in the Tractor cabin, to be used to send a global message to all connected Control Functions on the ISOBUS to go to an Idle/Shortcut state. This Functionality is not to be seen as an emergency button! The Functionality approach is flexible, and new functionalities that come up in the future can easily be added once the Guidelines are defined and released. Functionalities that are currently under development are for example: TIM / ISOBUS Automation and the TC-LOG, [2]

MATERIAL AND METHOD

2.1. Data Management

Data Management facilitates the exchange of data with the mobile equipment in the field. Through this functionality the user gets his data into a management system for registration purposes and further future planning.

Newly planned data can be generated by a decision support advisory systems and taken back into the farming equipment for planned field tasks and operations through for example a wireless service or telematics portal of the manufacturer, [10].

2.2. Connectivity

The end-customers, i.e. the farmers and contractors, expect a seamless connectivity of implements and tractors, regarding all systems and data, both in the field on his machines as well as to other software and services. An ‘open’ mind to connectivity with competitors and suppliers of Farm Management Software solutions and other Decision Management services is therefore a must for all companies and equipment manufacturers, [9].

2.3. Future Directions

Future challenges in ISOBUS development are focused at three points:

1. COPL (Cost Optimized Physical Layer):
   Cost optimization allowing a higher diffusion of the ISOBUS technology (also more suitable for smaller machines). The goal is to reach lower volumes and smaller application.
2. WIC (Wireless Infield Communication):
3. HIS (High Speed ISOBUS):
   – Distributed high-resolution position/correction signals.
   – Digital Video Systems.
   – Improved Service and Diagnosis (flash ECUs, Log-files, raw data streams for debugging).
   – Mobile Internet on ISOBUS for dedicated server/client requests.
   – High Voltage data Connection.

As technology evolves, manufacturers must take advantage of new opportunities with the end goal of providing farmers with a higher productive, higher quality and more efficient farming cycle, [3, 6, 11, 12 , 14, 15].

RESULTS

3.1. Overview of selected parameters for processing and monitoring of products of the market's leading agricultural machinery manufacturers

In first step of the research work the measured and processed parameters of most significant attached working equipment was defined.

The sprayers, fertilizer spreaders and seed drills (including towed-, and attached version, and also the direct-, and mulch sowing machines) and the ploughs were selected.

For machines listed in the measurement and processing of the measured values of the following parameters were determined:

a. Worked area
b. Theoretical quantity
c. Weighed quantity
d. Applied quantity
e. Time in working position
f. Distance in working position
g. Pump speed
h. Spray pressure
i. Hopper volume
j. Current speed
k. Speed source
l. Operating hours - motor
m. Current track width
n. Motor torque in %
o. Motor speed in rpm
p. Average consumption AdBlue in l/ha
q. Average consumption Diesel in l/ha
r. Current blower fan speed
s. Blower fan speed setpoint
t. Minimum speed
u. Maximum speed
v. Target speed
w. Spread rate actual value
x. Spread rate setpoint
y. Working position
z. Setpoint in per cent
aa. Theoretical residual quantity
bb. Hopper content
cc. Working width

3.2. The determination of monitored technical-technological parameters during the works of tractor and attached working machine combination

The next phase of work was the definition of the groups and subgroups of the technical-, and technological parameters which could be measured, processed and displayed during the works of tractor and attached working machine combination. These characteristics were classified into four main groups (Table 1.).

Table 1. The main groups of the technical and technological parameters

Quality of work	Power, and capacity-utilisation	Work safety	Cost

We denoted subgroups within the main groups, according to specificity, and the selected parameters were grouped in this way. The physical parameters which are the base of monitored technical and technological characteristics are presented in the Table 2 according to above illustrated classification.

To assure the quality of work it is important to ensure adequate working depth, tracking of the dispensed amount of input materials and analysis of energy consumption.
In terms of the power, and capacity-utilisation the area, the time, and the quantity (by volume or weight) proves to be key factors.

The work safety can be provided by the in time detection of crash, injury or by detection of early signs of developing malfunctions e.g. the formation of irregular resonance, or limitation of overload, and the monitoring of drivers behaviour.

From the users part it is essential to take into account the cost. From this perspective the labour cost, the machine work cost, and the cost of inputs are most determinative and it is primary to follow-up them.

Table 2.Recommended follow-up ISOBUS values

Quality of work	Power, and capacity-utilisation	Work safety	Cost
• Working depth • Measured value: • traction, drawbar deformation, • slip, • pitching angle of tractor	• Area • Measured value: • trip length, • Current speed, • Average speed, • attached machine width, • adjusted working width staging), • Direction of operation (coordinates)	• Crash, injury, resonance • Measured value: • engine oil viscosity, • temperature, • soot content, • hydraulic oil viscosity, • hydraulic oil temperature, • tire pressure, • vibration	• Labour • Measured value: • ID of vehicle card
• Dispensed amount of input material • Measured value: • PTO speed, • pump flow, • seed hopper weight, • seed plates speed, • fertiliser hopper weight, spreading disc speed	• Time • Measured value: • shift time, • engine operating hours	• Overload • Measured value: • gear, • motor temperature, • 3 point hitch height (working depth), • drawbar deformation, • PTO deformation	• Machine work • Measured value: • Work operation code, • Work operation date, • duration of work operations, • correction factor of work operations
• Energy consumption • Measured value: • fuel quantity, • actual fuel consumption, • exhaust gas temperature, • number of fuel card, • quantity and time of refuelling	• Volume or weight • Measured value: • seed hopper weight, • seed plates speed, • fertiliser hopper weight, • spreading disc speed	• Drivers behaviour • Measured value: • cabin temperature, • time of using automated steering, • field map setting	• Input material • Measured value: • amount of spreaded input materials, • area, distance × working width • unit price of inputs, • duration of the service, • cost of service

CONCLUSION AND RECOMMENDATIONS

The technical solutions provided by the ISOBUS system - registering of the operating parameters of power machine and attached equipment - could review not only the technical and service characteristics of operation of each machine.

There is an opportunity to overview the features on farm-management level that are the effective core devices for corporate governance, for efficient production and for successful planning too.

These data in case of high-volume machine fleet, whether it is farm-fleet or contractors fleet, makes transparent the administration of machines and the performed tasks by their. These can be defined as the effective modules of the company's management systems.

From technical approach it is essential to ensure compatibility of ISOBUS communication between the products of different producers, between the power machine and attached implement, and on the level of telemetrical data transfer too. Mostly the European market of agricultural machines is the main market where the multi brand interconnectivity represents the biggest challenge. This innovative market is that where the ISOBUS has the widest application.

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ODREĐIVANJE GLAVNIH PARAMETARA SISTEMA ISOBUS KAO OSNOV ZA UPRAVLJANJE POLJOPRIVREDNIM MAŠINAMA

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Sažetak: ISO organizacija (https://www.iso.org) je početkom 90-ih godina definisala industrijski standard za komunikacioni protokol između elektronskih uređaja različitih proizvođača poljoprivrednih mašina.

Nakon toga, svi tržišni akteri prepoznali su da je ova tehnologija veoma važna za elektroniku koja se koristi u poljoprivredi. Pojava proizvoda ISOBUS na tržištu u značajnijem obimu počinje sredinom 2000-te godine.

Opis ISOBUS tehnologije može se naći u standardu ISO-11783 (https://www.iso.org).

Kroz standarde i odgovarajuću tehničku pozadinu, opsežni menadžment podataka mogao bi pratiti i nadgledati mnogobrojne proizvodne procese i operacije u poljoprivrednoj proizvodnji. Legitimne potrebe poljoprivrednika i drugih korisnika i razvojni cilj je konstrukcija i primena sistema za podršku odlučivanju koji prate upotrebu mašina i osiguravaju kvalitet poslovanja. U tu svrhu je neophodno utvrditi koji tehnički, ekonomski, tehnološki parametri postaju neophodni za otkrivanje, merenje, prenos, obradu i procenu adekvatnih parametara u proizvodnji .

U radu je analizirano koje mehaničke karakteristike i parametre podešavanja u sistemu ISOBUS imaju najznačajniji proizvođači mašina koje se primenjuju u različitim poljoprivrednim operacijama.

Razvijen je sistem parametara i izvedenih karakteristika koji pružaju efikasno upravljanje poljoprivrednim površinama u slučaju priključene/korišćene opreme za rasipanje izlaznih materijala (seme, đubriva), sredstava za zaštitu bilja i obradu zemljišta.

Ključne reči: *ISOBUS, upravljanje podacima, upravljanje mašinama, poljoprivredna mehanizacija, razvoj proizvoda*

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DISTANCE-BASED VEGETATION INDICES COMPUTED BY SAGA GIS: A COMPARISON OF THE PERPENDICULAR AND TRANSFORMED SOIL ADJUSTED APPROACHES FOR THE LANDSAT TM IMAGE

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Abstract: Landsat-TM of 2001 covering Iceland (15.5°W-21°W, 64.5°N-67°N) was processed using SAGA GIS for testing distance-based Vegetation Indices (VIs): four approaches of Perpendicular Vegetation Index (PVI) and two approaches of Transformed Soil Adjusted Vegetation Index TSAVI. The PVI of vegetation from the soil background line indicated healthiness as a leaf area index (LAI). The results showed that the reflectance for vegetation has a linear relation with soil background line. Four PVI models and two TSAVI shown coefficients of determination with LAI. The dataset demonstrate variations in the calculated coefficients. The mode in the histograms of the PVI based on four different algorithms show the difference: -7.1, -8.36, 2.78 and 7.0. The dataset for the two approaches of TSAVI: first case ranges in 4.4.-80.6 with a bell-shape mode of a histogram (8.09 to 23.29) for the first algorithm and an irregular shape for the second algorithm with several modes starting from 0.11 to 0.2 and decreasing to 0.26. SAGA GIS permits the calculation of PVI and TSAVI by computed NDVI based on the intersection of vegetation and soil background. Masking the NIR and R, a linear regression of grids was performed using an equation embedded in SAGA GIS. The advantages of the distance-based PVI and TSAVI consists in the adjusted position of pixels on the soil brightness line which refines it comparing to the slope-based VIs. The paper demonstrates SAGA GIS application in agricultural studies.

Key words: *SAGA GIS, landsat TM, cartography, Vegetation Index, PVI, TSAVI, agriculture, mapping, iceland, environment*

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INTRODUCTION

Recently, vegetation indices computed using various GIS software based on the Landsat TM images have been often used in agricultural sciences to monitor vegetation and crop from space [43, 31].

The fundamental theoretical properties of this approach consists of a combinations of visible and near-infrared (NIR) spectral reflectance of various land cove types [1]. Because bare soils, vegetation, rocks, sand, urban spaces (eg. asphalt roads) and vegetation of various greenness have different spectral reflectance values [14, 22, 29], it can be used to detect the contours of these land cover types in general, and vegetation in particular using specially developed vegetation indices (VIs). As a result, various bands of the electromagnetic spectrum (red, green, blue, NIR) are being applied to monitor crop cover, health and yield, nitrogen stress, and soil moisture in agricultural mapping.

Quantitative indices of vegetation conditions are based on the principal contrast between the absorption and scattering of the R and NIR. Combined in mathematical equations, the VIs can give the numerical expression of the vegetation health. The most well-known VI is probably a normalized difference vegetation index (NDVI) often used in literature [17, 48, 49, 34, 35, 19]. The VIs correlate with the leaf greenness and canopy density. In this way, it indicates at the vegetation health [7].

The VIs are sensitive to the external factors: solar illumination, angle geometry, effects from the soil background and atmosphere (cloudiness, particles). The responses to the external factors are complex, reflecting surface background properties [47]. The NDVI is one of the slope-based VIs, in contrast with the distance-based VIs. The distance-based VIs (Perpendicular and Transformed Soil Adjusted VIs: PVI and TSAVI) corrected for the soil background effects are the aim of this study.

The study area is located in northern Iceland near the Eyjafjörður and the Skagafjörður fjords, the prosperous agricultural regions. The landscapes in northern Iceland are strongly affected by severe climate settings, glacier and ice coverage, and anthropogenic effects (cattle grazing). The geologic setting include Tjörnes Fracture Zone east of Eyjafjörður fjord which separates the northern volcanic zone of Iceland from the Kolbeinsey Ridge and has a sedimentary basin with 4 km of sediment thickness, [12].

The Tjörnes Fracture Zone presents an 80-km-wide zone of high seismicity, an oblique transform fault, along which shifted the rift zone in North Iceland joining the mid-ocean Kolbeinsey Ridge [20]. The western part of this basin has a graben with numerous listric normal faults which is a continuation of the spreading axis on the Kolbeinsey Ridge [21]. Complex geologic setting create conditions of volcanism which in turn cause the formation of the erosion -prone soils. As a result, one of the modern problems in today’s environment of Iceland is the land degradation and soil erosion, [16, 25]. At the same time, land cover and vegetation types distributed in Iceland present an important Nordic environment and habitat for fauna explaining the actuality of the study.

MATERIALS AND METHODS

Data

The data include the Landsat TM satellite image processed for the detection of vegetation and environmental monitoring in a northern region of Iceland by applying Perpendicular Vegetation Index (PVI).

The remote sensing data were processed in a SAGA GIS (System for Automated Geoscientific Analyses) software [6]. The Landsat TM data was captured in 08 August 2001 with the coordinates extent roughly 15.5°W-21°W, 64.5°N- 67°N (precise specification is given in Table 1). The WESN coordinates of the dataset are as follows: West: 19°43'06.88"W, East: 17°24'06.69"W, North: 66°38'00.38"N, South: 64°31'53.82"N. Resampling Technique: CC (Cubic Convolution), Product Type: Systematic Terrain (L1Gt), Datum: WGS84, Zone 27, Time Series: GLS2000, Orientation: NUP (North Up), Entity ID: P219R014_7X20010908, WRS Path 2019, WRS Row 14.

Algorithms

This study uses the PVI calculated for the study area. Although the NDVI is still a leading VI in remote sensing applications, the reason for using distance-based VIs is explained by the more sparse vegetation with requires adjusted equation to improve on the NDVI in the assessment of vegetation parameters. Thus, the main objective of the distance-based VIs is to remove the influence of soil brightness where vegetation is sparse and pixels contain a mixture of green vegetation and soil background.

The algorithm of the distance-based VIs consists in soil line calculation developed to minimize its influences. These indices are more reliable and less noisy than NDVI for sparse vegetation, although they are not widely used comparing to the NDVI. However, since vegetation in Iceland is in many areas sparse, these types of VIs can be suitable for the vegetation monitoring. The soil line represents a signature of soils in an R/NIR. The explanation of the correlation between VIs and spectral reflectance of vegetation is still subject to much discussion [24, 32, 33, 11].

Applications of the VIs can include Leaf Area Index (LAI) estimation by regressing the vegetation index against the measurements of plant parameter. Two variants of the VIs were calculated in this work, with the difference between them in the regression performed using the R or NIR bands as an independent variable. Hence, these VIs were tested in two groups: 1) PVI using R as independent variable [55, 47]; 2) PVI with NIR as as independent variable using existing approaches [50, 46].

SAGA GIS Methodology

The PVI calculation has been applied using the SAGA GIS module classified using path Geoprocessing>Imagery>Vegetation Indices>Vegetation Index (Distance Based). There are four perpendicular Vis, [50, 46, 55, 47] and two methods of the Transformed Soil Adjusted Vis, [3, 4]. These approaches have been tested and presented in this work for a comparative analysis in the algorithm of SAGA GIS and the output visualization.

In this work, the two VIs were used to estimate vegetation cover and the vigor of vegetation (greenness). The distance-based VIs that were calculated with SAGA GIS by two input raster layers of the Landsat TM image:

one with NIR band values and the second of R band values. Comparing to the slope-based VIs, the algorithm of the distance-based VIs is more complicated and require previous preparation of the image. Four perpendicular VIs have been computed in this study: 1) PVI [50]; 2) PVI [46]; 3) PVI [55]; 4) PVI [47].

Before the calculation of the distance-based VIs, the slope of the soil line and the interception of the soil line fields were calculated. The values were entered as the parameters in the SAGA GIS menu. This was achieved by the calculation of the NDVI as a slope-based VI. Using the computed NDVI, the areas that represent bare soil were selected. Afterwards, the raster grid containing ‘one’ in bare soil cells and ‘no data’ value in all the rest ones were created. The mask grid was applied to R and NIR raster grids.

A simple linear regression using the grids was performed thereafter using an equation ‘y = ax + b’, where ‘a’ is the slope of the soil line and b is the intercept. Thus, this linear regression of the NIR band against the R band is suitable for a sample of the bare soil pixels. Pixels near the soil line are interpreted as ‘soil’ class, while those with a distance far away are classified as ‘vegetation’.

RESULTS AND DISCUSSION

The spectral vegetation indices (VIs) use the well-known characteristic shape of the green vegetation spectrum by combining the low reflectance in the visible part of the spectrum with the high reflectance in the near infrared.

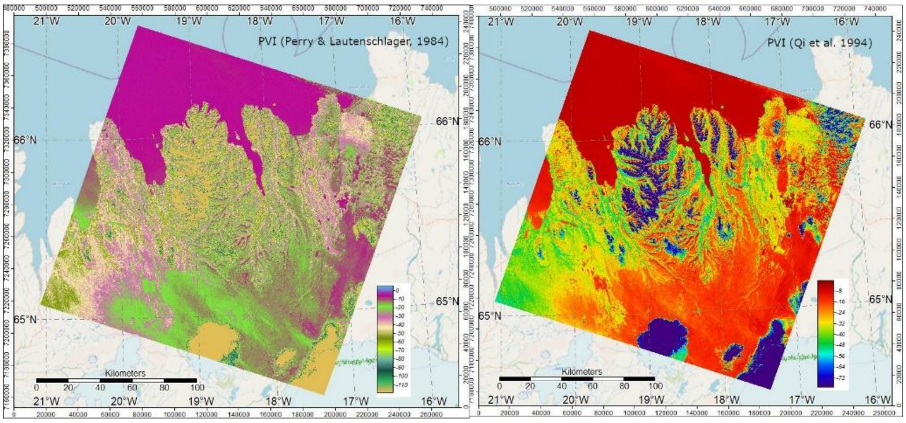

Figure 1. Left: PVI. Right: PVI. Mapping: SAGA GIS. Source: author.

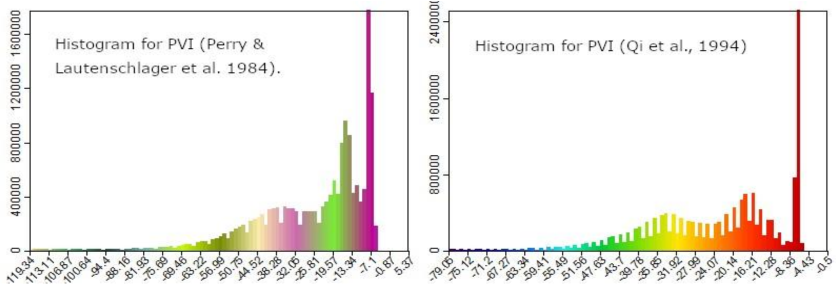

Figure 2. Histograms of pixels' frequency. Left: PVI (Perry & Lautenschlager et al., 1984). Right: PVI (Qi et al., 1994). Plotting: SAGA GIS. Source: author.

The combination may be in the form of a ratio, a slope, or some other formulation. Indices may be broadly separated into three categories:

1) intrinsic indices (such as the simple ratio and the NDVI), which do not involve any external factor other than the measured spectral reflectances;

2) soil-line related indices, which include soil-line parameters, such as the perpendicular VI (PVI), the weighted difference vegetation index, the soil-adjusted VI or SAVI [23], the transformed SAVI TSAVI [3].

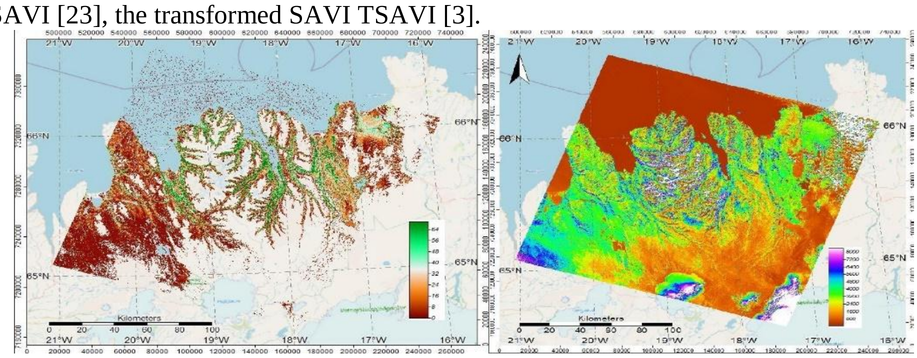

Figure 3. Left: PVI (Richardson & Wiegand, 1977), right: PVI (Walther & Shabaani, 1991). Mapping: SAGA GIS. Source: author.

The results of the applied methodology in the presented research is useful to the environmental scientists and agricultural crop studies applying SAGA GIS for analysis of sustainable development, land degradation and resource conservation.

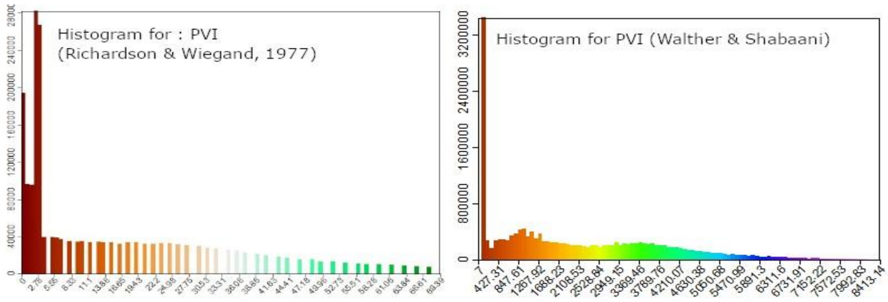

Figure 4. Histograms of pixels' frequency. Left: PVI (Richardson & Wiegand, 1977), right: PVI (Walther & Shabaani, 1991). Plotting: SAGA GIS. Source: author.

The results of this study present a comparative analysis of the VIs: PVI based on [46, 47] (Figure 1) and histogram (Figure 2). Showing the difference between these two approaches, it can be seen that the mode of the data set has a values of -7.1 for the case of [46] and -8.36 for the approach of [47]. Two minor peaks are notable for the ranges -56.99 to 25.81 and 19.57-13.34 for the first case and 43.7 to 27.99 with 20.14 to 16.21 for the second one.

In the output image in Figure 3 and Figure 4, the dataset and its histogram present approaches of PVI modelling by methods of [50] and [55] respectively. The histograms of both cases demonstrates similar behavior with a single mode in the lowest values. However, the absolute values differ according to the algorithm: the mode for the first case is 0-2.78 and the dataset extends to 69.39, while the second case has a peak in 7 to 427.31 and the dataset extends up to 8413.14, showing that the case of [50] is better calibrated.

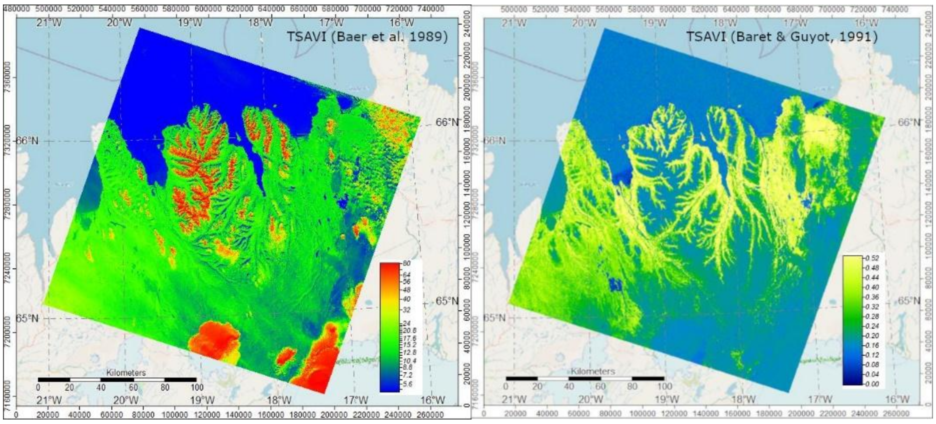

Figure 5. Left: TSAVI (Baert et al., 1989). Right: TSAVI (Baert & Guypt, 1991). Mapping: SAGA GIS. Source: author.

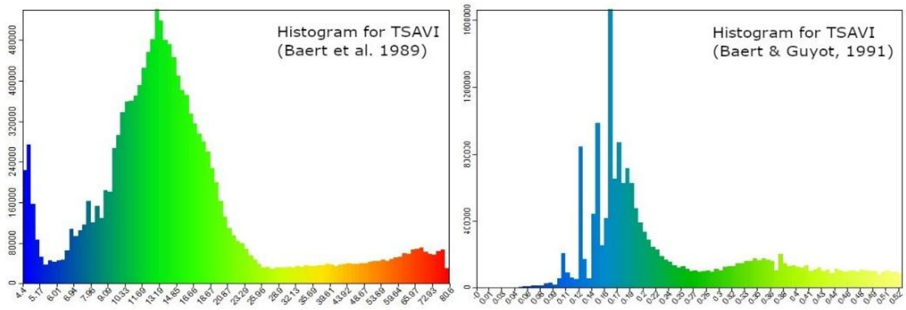

Figure 6. Histograms left: TSAVI (Baert et al., 1989), right: TSAVI (Baert & Guypt, 1991). Plotting: SAGA GIS. Source: author.

The dataset in Figure 5 and Figure 6 show the two approaches of the TSAVI computing. The dataset for the first case ranges from 4.4 to 80.6 with a bell-shape mode between 8.09 to 23.29 for the first case and an irregular shape.

The dataset of the last one is calibrated from 0 to 1 (more precisely, 0.0 to 0.62) with several modes starting from 0.11 to 0.2 and then progressively decreasing to 0.26.
A second slight increase in values can be seen in the interval of 0.33 to 0.38. The cartographic output image in Figure 7 shows the RGB color band composite (band 61-band 62-band 5).
However, the gain is set differently: band 61 is set to 'low' gain mode for the case of high surface brightness (e.g., desert, or less vegetated areas as in mountainous areas of Iceland). The band 62 is set to 'high' gain mode to maximize the instrument's 8-bit radiometric resolution without saturating the detectors. Both bands have identical detectors using the same wave width and band width.

The combination of the bands 61, 62 and 5 gives the effects of very bright ice-covered areas. The image on the right in Figure 7 shows the simulation of the Universal Image Quality Index and designed by modeling image distortion as a combination of factors: loss of correlation, luminance, contrast distortion. This research demonstrated testing and comparing the sensitivity of the distance-based VIs to remove soil background effects and better discriminate vegetation from the other land cover types, such as bare soils. The spectral reflectance of a vegetation, is a combination of the reflectance of plant leafs with soil, controlled by the optical properties of these elements. Logically, along with the growth of the vegetation, the soil contribution gradually decreases. However, it still remain a significant noise, depending on leaf density, canopy geometry, atmospheric effects (sun, wind). In this context, limitation of the soil reflectance and highlighting vegetation instead of soil background its the aim of the distance-based VIs, such as PVI and TSAVI simulating a typical healthy green canopy.

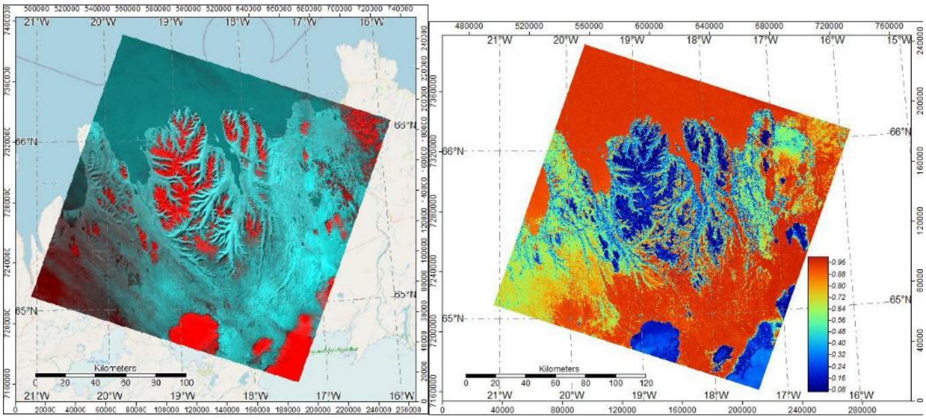

Figure 7. Left: RGB color band composite (band 61-band 62-band 5).
Right: Universal Image Quality Index. Mapping: SAGA GIS. Source: author.

CONCLUSION

This paper demonstrated the use of the computed and visualized PVI that takes into account the soil emissivity (one of the major drawbacks of NDVI) applied for the landscapes of Iceland.

However, extracting vegetation from the Landsat TM satellite image is often affected by the external atmospheric effects: clouds, pollutants, submicron particulate matter, which requires atmospheric correction and limits the application of the remote sensing.

The Landsat TM satellite imagery dataset can be used to compute the vegetation areas at a finer scale using the distance-based vegetation induces rather than traditionally used NDVI [2, 5, 8].

The results of the present work suggested that PVI can be used for accurate detection of vegetation in hardly accessible region of Iceland. As such, it allows more accurate environmental monitoring and agricultural management of Iceland, especially in the vulnerable areas with eroded soils [18] and as in certain regions of Iceland affected by climate change and glacier retreat [9, 10]. The presented models of PVI are based on varying algorithms developed concurrently by different author. In general, the behavior of the PVI is similar to Tasseled Cap greenness and the 2nd Principal Component in its approach. The PVI demonstrates to be less sensitive to the soil emissivity than other vegetation indices, like NDVI [13, 15] or SAVI [23].

Application of various machine learning methods in geosciences using algorithms of automatization allow precise cartographic mapping that significantly updates the traditional cartographic routine, through the application of scripting languages, [37, 38, 39, 51], which is noticeable in comparison to previous studies with traditional GIS applications, [53, 54, 44, 26, 27, 30, 45]. Supported by scripting approaches such studies rely on the processing of high-resolution datasets [36, 42]. Using machine learning methods in geosciences increases the speed of the data processing and the precision of the resulting graphs and maps.

However, in many cases, such as vegetation mapping, topographic or geologic variables are not enough to highlight the spatial characteristics of the environment. Taking into account satellite imagery brings cartography towards advanced modelling of the geographic phenomena: the regression models of the VIs are characterized by complex combination of several variables of spectral bands indicating vegetation contours. The exact combination of NIR/R and other variables varies, including previously calculated NDVI. The distance-based VIs differ in logic and technical workflow from the slope-based VIs. The advantage of the RS method of SAGA GIS for vegetation is the quality of image processing.

The SAGA GIS based mapping allows detailed determination of vegetation from other land cover types, enabling unequivocal separation of green areas from bare soils, water and urban spaces, as well as to assess the healthiness of leaf canopy. This is particularly important in zones where the vegetation areas are directly adjacent to other land cover types, or in unreachable areas where direct observations and fieldwork are difficult to undertake. Statistical data visualization and using computations and advanced methods of data processing are widely used in geosciences [28, 40, 41, 52]. The approaches of the remote sensing present a step forward in image processing for vegetation and agricultural mapping.

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DALJINSKI INDEKSI VEGETACIJE IZRAČUNATI PROGRAMOM SAGA GIS: POREĐENJE VERTIKALNOG I PRILAGOĐENOG PRISTUPA PROMENA ZEMLJIŠTA ZA SLIKU LANDSAT ™

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Sažetak: Landsat-TM slika je obrađena upotrebom SAGA GIS programa za testiranje indeksa vegetacije na osnovu udaljenosti u poljoprivrednim kartama: 4 pristupa indeksa vertikalne vegetacije (PVI) i 2 indeksa vegetacije TSAVI prilagođenog pristupa.

PVI vegetacije sa linije zemljišta (podloge) ukazivao je na zdravstvenu ispravnost kao indeks lisne površine (LAI). Refleksija vegetacije ima linearni odnos sa linijom pozadine.

Četiri PVI modela i dva TSAVI pokazala su koeficijente determinacije sa LAI. Podaci pokazuju varijacije u izračunatim koeficijentima. Način u histogramima PVI zasnovan na 4 različita algoritma pokazuje razliku: -7,1, -8,36, 2,78 i 7,0.

Skup podataka za 2 pristupa TSAVI: prvi slučaj kreće se u rasponu od 4.4 do 80.6 sa histogramom u obliku zvona (od 8.09 do 23.29) za prvi algoritam i nepravilnim oblikom za drugi algoritam sa nekoliko načina (0,11 do 0,2) i opadajućim do 0,26.
SAGA GIS program prikazuje vrednosti PVI i TSAVI izračunavanjem NDVI na osnovu preseka podataka vegetacije i pozadine podloge (zemljišta).
Upotrebom podataka NIR i R, urađena je linearna regresija pomoću jednačine ugrađene u SAGA GIS. Prednosti PVI i TSAVI sastoje se u prilagođenom položaju piksela na liniji osvetljenja zemljišta što poboljšava u odnosu na VI na temelju nagiba.

U radu je prikazana primjena SAGA GIS programa u poljoprivrednim studijama.

Ključne riječi: *SAGA GIS, Landsat TM, kartografija, indeks vegetacije, PVI, TSAVI, poljoprivreda, mapiranje, Island, životna sredina*

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GLOBAL MAPPER 15.0: A COMPARATIVE SOFTWARE TOOL IN THE DESIGN OF OPEN CHANNEL DRAINAGE SYSTEMS

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Abstract: This research aimed at computing peak flow discharge using state-of-the-art technology for watershed analysis to design a suitable open channel to minimize the effects of flood hazard during and after rainfall in an environment. A comprehensive topographical survey data obtained by Shuttle Radar Topographic Mission was employed in this study. The result of the survey shows that both the maximum and minimum elevation at 61.9 m and 51.1 m, respectively, and the mean slope of the area was 0.012. Watershed analysis of the study area was carried out using the Global Mapper15.0. The result shows that the parameters obtained such as the mean area of the sub-catchments is 1.43 ha, the mean length of channel flow is 99.33 m, the mean length of overland flow is 111.81 m, mean upstream elevation for overland flow is 63.30 m, mean downstream elevation for overland flow is 62.37 m and mean downstream elevation for channel flow is 61.12 m. The intensity duration frequency curve of the catchment was developed and a return period of 25 years was used to obtain an average rainfall intensity of 218.81 mm/hr. The peak discharge was obtained as 2.01 m^3/s using rational formula due to the area of the watershed being less than 80 hectares. Finally, several design parameters for the modeled rectangular channel were calculated. The result indicated that the width of the channel is 0.80 m and the depth of the channel is 1.0 m. The developed modeled channel has a design capacity of 2.03 m^3/s which is greater than watershed peak discharge 2.01 m^3/s. The size of the modeled channel was compared with the size of the existing channel and the result revealed that the existing drain was insufficient to carry the discharge from the catchment area due to its design capacity of 0.91m^3/s.

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It is recommended that the dimension of the existing drain should be increased to meet with the dimension of the modeled drain and a discharge point (safe outlet) should be provided.

Key words: *watershed, peak flow, Global mapper 15.0, open channel*

INTRODUCTION

Flood menace in Nigeria has become a normal and recurring phenomenon that sometimes has devastating impacts on human livelihoods and infrastructural development. This causes great concern in our immediate environment and country at large. A food is defined as an overflow of water that submerges usually dry land. A flood is defined as a covering by water of land not normally covered by water [1]. It can be caused by some factors such as rapid population growth, poor governance, poor drainage facilities and decaying infrastructures, poor practice of dumping waste/refuse. During heavy or long-duration rainfall events Eziobodo community experiences flood to a great extent especially along Federal University of Technology, Owerri (FUTO) Road. The existing drainage capacity provided along the road is not adequate, leading to stagnation of surface runoff for some period leading to flooding. The drainage system is covered with water in such a way that the drainage becomes invincible to the eye of those walking or driving along the road, this causes some motorcycles to fall inside those drains thereby making these individuals sustain injuries. The overtopping of water in the drains could be as a result of poor planning and design of the drainage system. For a drainage facility to be termed as poor it simply means that the drainage facility doesn't serve its required purpose. This could be as a result of wrong selection of the dimensions of the drain due to faulty mathematical equations used during the design or inaccurate hydrological studies of the area or some human activities such as dumping of refuse in the drains which hinders the free flow of water. This research aims at computing peak flow discharge using state-of-the-art technology for watershed analysis to design proper drain sizes and slopes to minimize the effects of flood hazards during and after rainfall events.

A watershed is defined as an area of land in which all of the incoming precipitation drains to the same body of water as a result of its topography [2]. In solving flood problems, watershed analysis can be employed through the use of remote sensing and GIS. One greater advantage of this is the ability to use GIS, which is a set of computerized tools for digital data processing, analysis, storage, retrieval and display of geographically referenced spatial information together with their attributes [3]. Watershed analysis refers to the process of using digital elevation models (DEM) and raster data operations to delineate watersheds and to derive catchment areas. from the flood affected catchment area using ArcGIS software, a geographic information system (GIS) software of which in this research was Global Mapper15.0 because it is more dedicated to watershed analysis due to its features.

This work aims to estimate the peak discharge of the affected catchment or watershed area which can be used to design a drainage system and compare the design dimensions with the already existing drainage channels in the catchment area.

To achieve the research aim, the specific objectives of the study shall include: carrying out a topographical survey of the area of study, carrying out watershed analysis of the selected catchment using Global Mapper15.0, carrying out rainfall analysis of the selected catchment, using Kerby-Kirpich formula to determine the time of concentration, using the rational formula in calculating discharge to obtain a result for smaller watershed areas, using the obtained peak discharge to determine the dimensions of the drain using open channel design equations, measuring the dimensions of the drain already existing in the affected area and compare with the calculated dimensions.

MATERIAL AND METHODS

The following materials were used for this research are:

- Digital imagery of the catchment area
- Shuttle Radar Topographic Mission (SRTM) data of the catchment area
- Intensity-Duration-Frequency Curve of the catchment area
- Global Mapper15 (GIS Software).

The following entails methods used in this research;

- Watershed analysis using Global Mapper GIS Software
- Kerby-Kirpich formula to calculate the time of concentration,
- Intensity-duration-frequency Curve used to obtain rainfall intensity,
- Rational formula to calculate peak discharge,
- Design equations to calculate dimension of an open channel

Study Area Description

The study area is Eziobodo community, which is one of the host communities of the Federal University of Technology, Owerri (FUTO), located in Owerri-West local Government Area (5.3669^{o}N, 7.0042^{o}E), of Imo State, Nigeria. Eziobodo is an Igbo-speaking community with a population of over 15,000 locals (2006 census). It is geospatially located in Universal Transverse Mercator (UTM) projected coordinate system, Zone 32N in datum WGS84 at coordinate 278835.69 East and 593603.73 N, 279285.77 Easting and 594211.05 Northing, 278129.98 Easting and 594959.76 Northing.

Watershed analysis using Global Mapper GIS Software

This software was primarily used to obtain areas of sub-catchments, upstream elevation along the main channel, downstream elevation along the main channel, upstream elevation along the overland, downstream elevation along the overland, length of overland and length of the channel. These parameters were obtained when the software was supplied with the SRTM data of the study area for the watershed analysis and calculate the time of concentration using the Kerby-Kirpich formula.

Kerby-Kirpich formula

The Kerby-Kirpich formula for estimating time of concentration (Tc) is applied to watersheds with areas ranging from 65 hectares to 38,850 hectares, main channel lengths between 1600 m and 80 km [4]. This method was used for obtaining the time of concentration for each of the sub-catchments, expressed by eq. (1) as:

$$T_c = T_{ov} + T_{ch} \tag{1}$$

Where: T_c = time of concentration, minutes;
T_{ov} = overland flow time, minutes;
T_{ch} = channel flow time, minutes

The Kerby Method

In small watersheds overland flow is an important component of overall travel time [5]. The Kerby equation is expressed as:

$$T_{ov} = K(L \times N)^{0.467} \times S^{-0.235} \tag{2}$$

Where: T_{ov} = overland flow time of concentration, minutes; K = a unit's conversion constant, K = 1.44; L = the overland-flow length, meters; N = a dimensionless retardance constant, N = 0.3; S = the dimensionless slope of terrain conveying the overland flow

The Kirpich Method

For channel-flow component of runoff, the Kirpich equation is applied thus to estimate the channel flow time [5]:

$$T_{ch} = K \times L^{0.770} \times S^{-0.385} \tag{3}$$

Where: T_{ch} = channel flow time, minutes; K = a unit's conversion constant, K = 0.0195; L = the channel flow length, meters; S = the dimensionless main-channel slope.

Intensity Duration Frequency Curve

The time of concentration obtained from the use of kerby-kirpich formula was used to obtain corresponding rainfall intensity using the IDF Curve of the catchment area. The rainfall intensity was obtained based on the design return period of 25 years for drain channels.

Rational formula

This formula is appropriate for urban and rural watersheds less than 200 acres (80 hectares) with generally uniform surface cover and topography that is best suited for the catchment area [5]. This formula is used only to compute peak runoff rates.

The area of the sub-catchments obtained from watershed analysis and the rainfall intensity obtained from the intensity-duration-frequency curve were used to estimate the peak discharge rate using the rational formula, given as:

$$Q = \frac{CIA}{Z} \tag{4}$$

Where: Q and C are the peak discharge rate (m^3/s) and runoff coefficient, respectively;

I = average rainfall Intensity (mm/hr);
A = drainage area (ha);
Z= conversion factor, 360 for metric.

Open channel design

The design of the open channel considered the bottom-width (b); depth of flow (d), velocity of flow (v) and the anticipated discharge from the selected channels. It also comprises of the sectional area (A), wetted perimeter (P), the hydraulic radius (R) and the Manning's velocity (V). However, for rectangular channel, the cross-sectional area is given as:

$$A = bd \tag{5}$$

Where:
A = cross-sectional area, m^2; b = bottom width, m; d = depth of flow, m

For rectangular channel; the wetted perimeter is estimated as:

$$P = b + 2d \tag{6}$$

Where:
P = wetted perimeter, m.

The hydraulic radius of the channel is given as:

$$R = \frac{A}{P} \tag{7}$$

Where:
R = hydraulic radius, m.

The velocity of flow is determined using the manning's formula, expressed in eq. (8) as:

$$V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \tag{8}$$

Where:
V = velocity of flow, m/s; n = Manning's roughness coefficient; S = bed slope of channel.

The bed slope is expressed as:

$$S = \frac{\Delta H}{L_c} \tag{9}$$

Where:
ΔH = difference between the highest and lowest elevation (m); L_c=length of channel (m).

The discharge capacity, Q_c of the channel is given by:

$$Q_c = AV \tag{10}$$

Where:
Q_c = Discharge capacity of channel, m^3/s.

Design dimensions
The adequate dimensions of the drain as shown in Tab. 6 was obtained through the use of manning's formula using the open channel design equations, as well as trial-and-error approach.

Hydraulic Analysis
Rectangular section

b = 0.80 (assumed), d = 0.83 (assumed), S = 0.012, n = 0.015 (Tab. 7), Q_p = 2.01 m^3/s (Tab. 5).

Area of channel, $A_c = b \times d = 0.80 \times 0.83 = 0.664\,m^2$

Wetted perimeter, $P_w = b + 2d = 0.80 \times (2 \times 0.83) = 2.460\,m$

Hydraulic Radius, $R_h = \frac{A_c}{P_w} = \frac{0.664}{2.460} = 0.270m$

Velocity of flow, $V_f = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} = \frac{1}{0.015} \times (0.270)^{\frac{2}{3}} \times (0.012)^{\frac{1}{2}} = 3.05\,m/s$

Discharge capacity of channel, $Q = A_c \times V_f = 0.664 \times 3.05 = 2.03\,m^3/s$

Assuming a freeboard of 20%

Freeboard, $F = \frac{20 \times d}{100} = \frac{20 \times 0.83}{100} = 0.17\,m$

Hence Depth, $D = d + F = 0.83 + 0.17 = 1.0\,m$

RESULTS AND DISCUSSION

Topographical survey

Fig. 1 illustrates the undulating topographic pattern of the study area, with a maximum and minimum elevation of 61,9m and 51,1m, respectively.

A topographic survey was carried out along FUTO-Eziobodo road as shown in Tab. 1. The slope of the land area was obtained to be 0.012 and also used to generate the SRTM data for the study area. The global mapper 15.0 software was used to generate the different sub-catchments contributing to the flow-line that approaches FUTO road. It was used to estimate the area, length of channel (L_{ch}), length of overland (L_{ov}), upstream (H_1) and downstream (H_2) elevations for overland, respectively; and downstream elevation for channel (H_3) for all the sub-catchments as shown in Tab. 2.

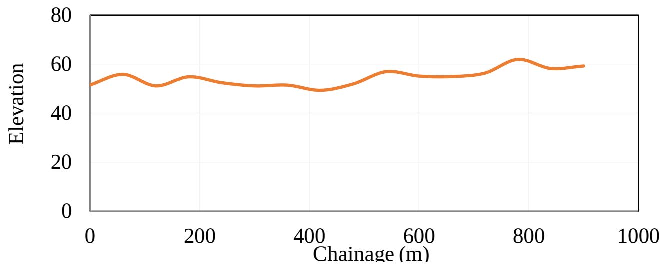

Figure 1. Topographic array of FUTO-Eziobodo road

Table 1. Topographical survey data along FUTO-Eziobodo road

Chainages (m)	Easting	Northing	Elevation(m)
0+000	278613.7	594251.2	51.5
0+060	278574.1	594302.0	55.8
0+120	278537.4	594352.1	51.1
0+180	278502.2	594395.9	54.8
0+240	279286.5	594439.1	52.4
0+300	278430.0	594484.6	51.1
0+360	278395.0	594528.9	51.4
0+420	278358.8	594584.9	49.3
0+480	278335.1	594629.5	51.9
0+540	278299.8	594683.0	56.9
0+600	278263.4	594731.5	55.1
0+660	278211.4	594776.1	54.9
0+720	278167.1	594816.4	56.3
0+780	278147.8	594875.6	61.9
0+840	278132.5	594934.3	58.2
0+900	278130.0	594959.8	59.2

Table 2. Watershed analysis of the catchment area

Sub-catchments (SC)	Area (ha)	L_{ch} (m)	L_{ov} (m)	H_1 (m)	H_2 (m)	H_3 (m)
SC_1	2.75	198.92	221.22	62.387	62.323	60.671
SC_2	0.755	70.51	94.966	64.505	62.501	61.843
SC_3	9.489	433.75	364.18	63.858	63.46	60.894
SC_4	0.3429	69.352	53.424	62.279	60.305	59.671
SC_5	0.4514	76.59	45.008	63.142	61.611	60.664
SC_6	1.714	86.756	191.59	63.142	63.05	61.514
SC_7	1.969	86.756	147.0	63.821	62.959	61.041
SC_8	0.92	74.053	68.85	63.833	62.721	60.787
SC_9	0.544	86.317	50.628	63.766	62.698	61.828
SC_{10}	0.3223	98.689	39.031	63.877	62.516	61.845
SC_{11}	0.571	77.425	71.339	63.83	62.909	61.227
SC_{12}	1.571	98.33	125.39	62.922	62.896	60.604
SC_{13}	0.3818	107.03	32.435	62.921	61.742	60.629
SC_{14}	0.4583	79.672	48.543	62.935	62.246	60.943
SC_{15}	0.4775	72.372	6.828	62.926	61.869	61.766
SC_{16}	0.2217	72.372	28.85	62.601	62.048	61.959

From Tab. 2, it is observed that increase in the area of the sub-catchment results in an increase in the length of channel and length of overland. The Sub-catchment 3 has the maximum area and also has the maximum length of channel and length of overland compared to other Sub-catchments.

Intensity duration frequency (IDF) curve

The intensity duration frequency (IDF) curve of the study area (Fig. 2) was generated using meteorological data from Nigerian Meteorological Agency and ArcGis Software.

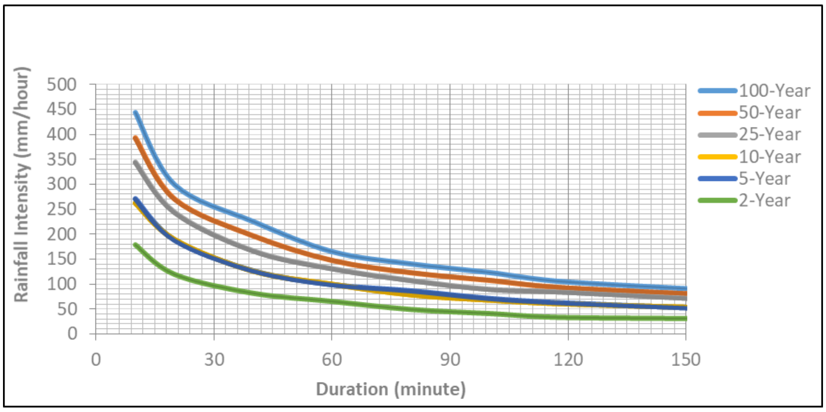

Figure 2: Intensity-Duration-Frequency (IDF) Curve for Owerri

The legend in the graph represents the return period (which is the average interval of time within which the magnitude of the rainfall event will be equaled or exceeded once) used in the design of hydraulic structures. In this research, a 25-year return period was adopted because, it is used for urban drainage works. From the IDF curve, it can be observed that the higher the time of concentration (duration) the lesser the rainfall intensity.

Time of concentration

The time of concentration (T_c) for every sub-catchment as shown in Table and 3 was obtained by summing the time of overland flow (T_{ov}) and time of channel flow (T_{ch}).

Table 3. Time of concentration (Tc) for different sub-catchments

Sub-Catchment (SC)	T_{ov} (mins)	T_{ch} (mins)	T_c (mins)
SC_1	64.3	8.2	72.5
SC_2	13.8	4.4	18.2
SC_3	72.4	12.3	84.7
SC_4	13.7	2.3	16.0
SC_5	15.6	1.6	17.2
SC_6	33.0	7.2	40.1
SC_7	19.5	4.8	24.3
SC_8	16.4	2.0	18.4
SC_9	18.5	1.9	20.4
SC_{10}	19.2	1.6	20.7
SC_{11}	17.7	2.2	19.9
SC_{12}	48.5	3.8	52.2
SC_{13}	21.0	1.0	22.0
SC_{14}	19.4	1.6	20.9
SC_{15}	16.4	0.4	16.8
SC_{16}	19.1	2.4	21.5

From Tab. 3, it can be observed that SC_3 has the highest T_{ov} of 72.4 mins, because of the magnitude of its L_{ov} and SC_4 has the lowest T_{ov} of 13.7mins due to its L_{ov}. That is, the greater the L_{ov}, the greater the T_{ov}. The SC_3 has the highest T_{ch}, 84.7 mins because of the magnitude of its L_{ch} and SC_{15} has the lowest T_{ch}, 0.4 mins due to its L_{ch}. That is, the greater the L_{ch}, the greater the T_{ch}. Also, SC_3 has the highest $T_{c,}$ 84.7 mins because of the magnitude of its catchment area and Sub-catchment 4 has the lowest T_c, 16.0 due to its small catchment area.

Rainfall intensity

The time of concentration for each of the sub-catchment in Tab. 3 was used to obtain the corresponding intensity of rainfall (mm/hr.) as shown in Tab. 4, for 25 years return period from the IDF curve shown in Fig. 2.

Table 4. Rainfall intensity using T_c for each sub-catchment on IDF curve

Sub-catchment (SC)	T_c (mins)	Rainfall intensity, I (mm/hr.)
SC_1	72.5	115
SC_2	18.2	244
SC_3	84.7	106
SC_4	16.0	275
SC_5	17.2	270
SC_6	40.1	163
SC_7	24.3	220
SC_8	18.4	242
SC_9	20.4	248
SC_{10}	20.7	245
SC_{11}	19.9	250
SC_{12}	52.2	140
SC_{13}	22.0	230
SC_{14}	20.9	240
SC_{15}	16.8	270
SC_{16}	21.5	243

Sub-catchments discharge

The discharge of the sub-catchments (Tab. 5) was obtained using the rational formula. The runoff coefficient (C), 0.4 was selected based on the type of drainage area.
The total discharge from the sub-catchments was obtained to be 4.02 m^3/s (Tab.5.) and the total peak design discharge was divided into two to obtain 2.01 m^3/s, which was used to design for the open channel that should be provided on both sides of the road.

Table 5. Design discharge for each of the sub-catchment

Sub-catchment (SC)	Runoff Coefficient, C	Rainfall Intensity, I (mm/hr.)	Area (ha)	Discharge, Q (m^3/s)
SC_1	0.4	115	2.75	0.35
SC_2	0.4	244	0.755	0.20
SC_3	0.4	106	9.489	1.12
SC_4	0.4	275	0.3429	0.10
SC_5	0.4	270	0.4514	0.14
SC_6	0.4	163	1.714	0.31
SC_7	0.4	220	1.969	0.48
SC_8	0.4	242	0.92	0.25
SC_9	0.4	248	0.544	0.15
SC_{10}	0.4	245	0.3223	0.09
SC_{11}	0.4	250	0.571	0.16
SC_{12}	0.4	140	1.571	0.24
SC_{13}	0.4	230	0.3818	0.10
SC_{14}	0.4	240	0.4583	0.12
SC_{15}	0.4	270	0.4775	0.14
SC_{16}	0.4	243	0.2217	0.06

Design comparison

The design parameters of the modeled channel shown in Tab. 6 were compared to the design parameter of the existing channel as shown in Tab. 8.

Table 6. Design parameters of the modeled rectangular drain

Shape	Rectangular
Width, b (m)	0.80
Depth, d (m)	0.83
Bed slope, S (%) (Table 1)	1.2
Area, A (m^2)	0.664
Wetted perimeter, P (m)	2.460
Hydraulic radius, R (m)	0.270
Manning's coefficient, n	0.015
Velocity of flow (m/s)	3.05
Peak discharge, Q (m^3/s)	2.03
Total depth, D (m)	1.0
Freeboard (20%)	0.17

Table 7: Manning's roughness coefficient, (n), [6]

Type of gutter or pavement	Manning's, n
Concrete gutter, troweled finish	0.012
Asphalt pavement: smooth texture	0.013
Asphalt pavement: rough texture	0.016
Concrete gutter with asphalt pavement: smooth texture	0.013
Concrete gutter with asphalt pavement: rough texture	0.015
Concrete pavement: float finish	0.014
Concrete pavement: broom finish	0.016
Note: For gutters with a small slope or where sediment may accumulate, increase n-values by 0.02(USDOT, FHWA, 2001).	

Table 8. Comparison of channel along FUTO-Eziobodo road

Existing Channel Parameters		Modeled Channel Parameters	
Shape	Rectangular	Shape	Rectangular
Width(m)	0.65	Width(m)	0.92
Depth (m)	0.63	Depth (m)	1
Bed Slope (%)	0.86	Bed Slope (%)	1.2
Peak Discharge (Q)(m^3/s)	0.91	Peak Discharge (Q) (m^3/s)	3.11

The data in Tab. 8 shows that the existing channel capacity did not meet up to the discharge from the catchment area with the existing channel capacity of 0.91 m^3/s whereas the discharge from the catchment area was 2.01 m^3/s.

The insufficiency of the existing drain results to the cause of flooding during rainfall events because the drain section fills up easily and begins to overflow to adjoining areas of the catchment and also the abrupt termination of the existing channel without an outlet also resulted in the flow building up in the channel which overflows onto the surroundings the channels are overtopped.

CONCLUSIONS

In this work which was aimed at computing peak flow discharge using state-of-the-art technology for watershed analysis to design a suitable open channel to minimize the effects of flood hazard during and after rainfall in an environment. The following conclusions are depicted:

- The topographical survey of the study area was carried out; the results of the survey show that maximum and minimum elevations obtained were 61.9 and 51.1m, respectively; whereas the mean slope of the area is 1.2%.
- Watershed analysis of the study area was also carried out using the Global Mapper 15.0 tool. From the results, the parameters obtained such as the mean area of the sub-catchments, mean length of channel flow, mean length of overland flow, mean upstream elevation for overland flow, mean downstream elevation for overland flow, and mean downstream elevation for channel flow were 1.43 ha, 99.33 m, 111.81 m, 63.30 m, 62.37 m and 61.12 m, respectively.
- The intensity duration frequency curve of the study area was developed. The average rainfall intensity of all the sub-catchments using a return period of 25 years was obtained as 218.81 mm/hr.

- The Kerby-Kirpich formula was used to obtain the time of concentration of all the sub-catchments. The result shows that the meantime of concentration is 30.4 mins.
- Furthermore, the results from the hydrological analysis of the study area were used to determine the peak discharge of 2.01 m^3/s on both side of the catchment using the rational formula.
- Also, the hydraulic analysis was carried out using the peak discharge of 2.01 m^3/s to design for a rectangular channel section having a width of 0.80 m and a depth of 1.0 m with a bed slope of 0.012.

Finally, the comparisons between the two channels show that the existing channel capacity did not meet up to the discharge from the catchment area with the existing channel capacity of 0.91 m^3/s while the discharge from the catchment area was 2.01 m^3/s. Therefore, the dimensions of the existing channel are insufficient and should be modified to fulfil its purpose of channeling water without overtopping.

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GLOBAL MAPPER 15.0: UPOREDNI PROGRAMSKI ALAT ZA DIZAJN OTVORENIH KANALSKIH SISTEMA ZA ODVODNJAVANJE

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Sažetak: Istraživanje ima za cilj izračunavanje najvećeg protoka pomoću najsavremenije tehnologije za analizu sliva kako bi se dizajnirao odgovarajući otvoreni kanal i umanjili efekti opasnosti od poplave tokom i nakon kiša u okruženju.

U ovoj studiji korišćeni su sveobuhvatni podaci o topografskim istraživanjima dobijeni od topografske misije Shuttle Radar Topographic Mission.

Rezultat istraživanja pokazuje da su maksimalna i minimalna nadmorska visina od 61,9 m, odnosno 51,1 m, a srednji nagib područja bio je 0,012. Analiza sliva istraživanog područja izvršena je pomoću programa Global Mapper verzija 15.0.

Rezultat pokazuje dobijene parametre: srednja površina podsliva 1,43 ha, srednja dužina protoka kanala 99,33 m, srednja dužina kopnenog toka 111,81 m, srednja nadmorska visina nadzemnog toka 63,30 m , srednja nadmorska visina za kopneni tok je 62,37 m, a srednja nadmorska visina za protok kanala je 61,12 m.

Kriva frekvencije trajanja intenziteta padavina u slivu je razvijena i upotrebljen je kontrolni period od 25 godina da bi se dobio prosečan intenzitet padavina od 218,81 mm/sat. Najveći protok je dobijen kao 2,01 m^3/s koristeći racionalnu formulu zbog površine sliva manjeg od 80 ha.

Konačno, izračunato je nekoliko projektnih parametara za model pravougaonog kanala. Rezultat je pokazao da je širina kanala 0,80 m, a dubina kanala 1,0 m. Razvijeni model kanala ima projektni kapacitet od 2,03 m^3/s što je veća vrednost od najvećeg protoka sliva od 2,01 m^3/s.

Veličina modela kanala upoređena je sa veličinom postojećeg kanala, a rezultat je pokazao da postojeći profil odvoda nije dovoljan za odvođenje vode iz sliva zbog njegovog manjeg projektnog kapaciteta od 0,91 m^3/s.

Preporuka je da se dimenzija postojećeg kanala poveća tako da se zadovolji sa dimenzijom modelovanog odvoda kanala i obezbedi mesto ispuštanja vode (siguran izlaz).

Ključne reči: *sliv, najveći protok, Global maper 15.0, otvoreni kanal*

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EFFECTS OF PRETREATMENT AND DRYING TEMPERATURE ON ANTIOXIDANTS AND ANTINUTRIENTS OF *Justicia insularis* AND *Jatropha tanjorensis* LEAVES

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Abstract: Antioxidants and antinutrient contents of leafy vegetables may be influenced by post-harvest processing. The present study was carried out to assess the effect of pretreatments (P) and drying temperatures (T) on antioxidants and antinutrients of *Justicia insularis* and *Jatropha tanjorensis* leaves. Four groups of samples were prepared, namely: fresh sample (FR), un-blanched and dried sample (UB), sample blanched in hot water and dried (BHW) and sample blanched in salt water and dried (BSW). Drying was conducted at 40 ^{0}C, 50 ^{0}C and 60 ^{0}C using hot air oven. Antioxidants and antinutrients of the samples were determined. The data collected were subjected to a two-way Analysis of Variance (ANOVA) as well as Dunnett t-test at 5% probability level. Based on the results, BHW between 50^0 C and 60^0 C increased the antioxidant activity in both vegetables. BHW 60 ^{0}C was able to reduce oxalate and phytate contents to reasonable level while BSW50 ^{0}C drastically decreased hydrogen cyanide and tannin contents. However, the overall, individualistic, and interactive effects of P and T had significant (P_{cal} < 0.05) influence on majority of antioxidant activity and antinutrient contents in both vegetables.

Key words*: Justicia insularis, Jatropha tanjorensis, pretreatment, drying temperature, antioxidants, antinutrients*

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INTRODUCTION

Vegetables are succulent part(s) of plant which could be eaten raw, cooked with other dishes, as an appetizer or salad [1]. Some of them include pumpkin, cabbage, carrot, garden egg, *Justicia insularis* and *Jatropha tanjorensis*, etc. They are key ingredients in many processed foods and pharmaceutical products [2]. *Justicia insularis,* commonly called "hunter's weed" is an herb of the family *Acanthaceae* with angular stem, and swollen aerial root at basal part of the stem [3]. The leaves are used as food ingredient especially for infants and as healing balm in some parts of West Africa [4]. Similarly, *Jatropha tanjorensis,* otherwise known as "hospital-too-far", belongs to the family of *Euphorbiacea* and is widely grown in the tropics [5]. The leaves are used as food ingredient and also employed in the traditional treatment of many diseases such as anaemia, diabetes and cardiovascular diseases [4]. Both vegetables contain essential food nutrients such as vitamins, minerals, fibre, carbohydrate, protein, natural antioxidants as well as traces of antinutrients [6,4,5]. However, antioxidants are free radical scavengers (e.g. carotenoids, folic acid, tocopherols, phenolic compounds, etc) that protect the harmful effects of reactive oxygen species such as hydroxyl radicals and peroxides [7]. Excess of these free radicals in the human body can lead to development of chronic diseases such as cancer, arteriosclerosis, nephritis, diabetes mellitus, etc [8]. Hence, natural antioxidants play a vital role in maintaining and preserving good health [9]. Conversely, antinutrients are natural or synthetic compounds found in a variety of plants that can inhibit the absorption of food nutrients in humans [10], e.g. oxalate, hydrogen cyanide, tannin, phytate, saponins, flavonoid, alkaloids, amongst others. Since both vegetables are perishable and the nutritional contents are very essential, preservation of the plant leaves is necessary. Several methods of preserving vegetables in terms of antioxidant retention or increase and reduction of antinutrients to minute level have been reported [11, 12, 13]. It has been found that pretreatment methods (e.g. blanching, cooking, boiling, etc.), blanching time, drying temperature could significantly affect antioxidants and antinutrients in fruits and vegetables [14, 15, 16; 17, 18, 19, 20, 21]. In an effort to preserve or retain antioxidant contents, and to reduce antinutrients to safe level, it was necessary to investigate the most suitable pretreatment and drying temperature combination that will give the product the desired quality. However, in this study the antioxidants considered were phenolic compounds while that of antinutrients were oxalate, hydrogen cyanide, tannin and phytate. The major objective of this study is to evaluate the effects of processing temperature and pretreatments on antioxidant and antinutrient content of *Justicia insularis* and *Jatropha tanjorensis* leaves.

Fig. 1. *Justicia insularis* plant

Fig. 2. *Jatropha tanjorensis* plant

MATERIAL AND METHODS

Preparation of Fresh and Dried Samples

About 200 g each of *Justicia insularis* and *Jatropha tanjorensis* leaves were sourced from a local farmer in Uyo, Akwa Ibom State. The leaves were carefully washed with distilled water to remove the dirt, and wiped with a lint free towel. They were divided into four groups, namely group I, II, III and IV. Group I was regarded as fresh sample. Group II was blanched in hot water where it was placed in a sieve and immersed in a thermostatic water bath at 95 ^{0}C for 2 minutes. The samples were then subjected to running water at 4 ^{0}C for 2 minutes. They were later exposed to air for 20 minutes and wiped with a lint free towel. Group III was blanched in 10% brine solution and followed by the same procedures carried out in Group II. Group IV was untreated. Each of the group was divided into three (3) sets before subjected to oven drying using a hot air dryer Genlab model DC 125 in Food Engineering Laboratory, University of Uyo, Uyo, Nigeria, at temperature of 40^{0}C, 50^{0}C and 60^{0}C, respectively in duplicate. The range of temperature and brine solution used in this experiment was as found in literature [22, 23]. Each dried sample was ground into powder, bottled and labelled and was used for analysis.

Preparation of Sample Extract

The mixture of the sample (3.0 g) and 20 ml of 95% ethanol was mechanically shaken for 2 hours (Griffin Flash shaker, London) and centrifuged at 3,650 rpm for 35 minutes at 4°C (Anke DL-6000 B, China). The residue was re-extracted under the same conditions and both supernatants were collected and adjusted to 40 ml with 95% ethanol. All extracts were filtered through Whatman N°1 filter paper and stored at 4°C until analysis, [24].

Determination of Antioxidant Activity

The antioxidant activity was assessed using the following assays

Determination of Total Phenolic Content (TPC)

Total phenolic content (TPC) was determined using the procedure described by Bakar, Mohamed, Rahmat & Fry, [25]. Folin–Ciocalteu reagent (2.25 ml) was diluted ten-fold with distilled water and the extract (300 μl) added. Na_2CO_3 solution (2.25 ml) was mixed with the set up and was allowed to react for 5 mins at room temperature. After incubation for 90 mins at room temperature, absorbance was read at 725 nm using spectrophotometer. The concentration was expressed as mg gallic acid equivalents in 1 g of dried sample (mg GAE/g db).

Determination of 2, 2-Diphenyl-1-Picryl Hyrazyl (DPPH) Radical Scavenging Activity

The DPPH radical scavenging activity was determined based on the method described by Gulluce, Sahin, Sokmen, Ozer, Daferera, Sokmen, Polissiou, Adiguzel & Ozkan, [26].

A mixture of aqueous sample extract (0.1 ml) and 0.004% methanolic solution of DPPH (3 ml), was prepared. Absorbance of the mixture was read at 517 nm after 30 mins using spectrophotometer. The capacity to scavenge the DPPH radical was found using Equation 1:

$$\text{DPPH scavenging activity (\%)} = \left(\frac{A_w - A_e}{A_w}\right) \times 100 \qquad (1)$$

where $A_w =$ absorbance without extract and A_e = absorbance with extract.

Determination of Cupric Ion Reducing Antioxidant Capacity (CUPRAC)

CUPRAC was determined using the method described by Sethi, Joshi, Arora, Bhowmik, Sharma & Kumar, [27]. A mixture of sample extract (0.1 ml) and distilled water (1 ml) was made. This was followed by addition of $CuCl_2$, neocuproine and ammonium acetate buffer (pH 7) (CH_3COONH_4) solution in 1:1:1 to obtain total reaction mixture of 4.1 ml. After 30 minutes of incubation at room temperature, absorbance was read at 450 nm using spectrophotometer. The result was expressed as μmol Trolox / g dry sample.

Determination of Ferric Reducing/Antioxidant Power (FRAP)

FRAP was determined using the method described by Butsat and Siriamornpun [28]. The FRAP solution is a mixture of 10 mM tripyridyltriazine solution, 40 mM HCl, 20 mM $FeCl_3$ solution, 300 mM acetate buffer and pH 3.6. The fresh solution was heated to 37 ºC before use. A mixture of 100 μl of sample extract (100 μl) and FRAP solution (1.9 ml) was prepared. The absorbance of the mixture was read at 593 nm after 60 mins using spectrophotometer. The concentration of the sample was extrapolated from the standard curve prepared with known concentrations of $FeSO_4$ in μmol $FeSO_4$/g dry sample.

Determination of Antinutrient*s*

The following antinutrients were determined:

Determination of Oxalate Content

The oxalate content of the ground sample was determined using titration method as described by Association of Official and Analytical Chemists [AOAC] [29].

A mixture of ground sample (5 g), distilled water (95 ml) and 5.0 ml 6N HCl in a beaker was heated in a water bath at 50 ^{0}C for 2 hours. Then, distilled water (126 ml) was added to the digest. The filtrate (50 ml) with methyl red indicator (few drops) in a beaker was evaporated. Ammonium hydroxide (5 ml) was added to the resulting filtrate, and heated to 90 ^{0}C, while 5% calcium chloride (10 ml) solution was added, stirred and kept overnight at 5 ^{0}C. The precipitate obtained from centrifugation and filtration was washed with 10 ml of 20% v/v H_2SO_4 and diluted with 125 ml distilled water.

Finally, aliquot solution (125 ml) was heated and titrated against 0.05 N standardized $KMnO_4$ solution to a faint pink colour.

Determination of Hydrogen cyanide (HCN)

Hydrogen cyanide in the ground sample was determined using alkaline picrate *method* (Nwokoro, Ogbonna & Okpala [30]. The mixture of ground sample (5 g) and in 50 ml distilled water in conical flask was corked, and the extract left overnight and later filtered.

Different concentrations of KCN solution containing 5 - 50 mg cyanide and 1 N HCl (25 ml) were used to prepare cyanide standard curve. A mixture of filtrate (1 ml) and alkaline picrate (4 ml) in a test tube was incubated in a bath for 15 minutes to develop reddish brown colour. The absorbance was read using spectrophotometer at 490 nm. The blank absorbance containing only 1.0 ml distilled water and 4.0 ml alkaline picrate solution was also read. The hydrocyanide content was extrapolated from the standard cyanide curve and expressed in mg /100 g dry sample.

Determination of Tannin

The tannin content was determined using Folin Denis Reagent as described by Makkar, Blummel, Borowy & Becker [31]. Furthermore, a mixture of ground sample (2 g) and 70% acetone (10 ml) in a corked bottle was placed in ice bath centrifuge at 4°C for 6 min. The 0.2 ml of cold –stored supernatant solution was pipetted into distilled water (0.8 ml). Standard solution of tannin acid ($C_{76}H_{52}O_{46}$) was also prepared. Folin reagent (0.5 ml) was added to both sample and standard followed by 20 % Na_2CO_3 (2.5 ml). The solution was incubated at room temperature for 40 minutes. Then, the absorbance was read at 725 nm. The concentration of tannin was estimated from the standard tannic acid curve and expressed in mg /100 g dry sample.

Determination of Phytate Content

Phytate content was determined using the method described by AOAC [29]. Moreover, a mixture of finely ground sample (2.0 g) and 0.2 N HCl (20 ml) was filtered. The mixture of filtrate (0.5 ml) and ferric ammonium iron (III) sulphate (1 ml) solution in a test tube was boiled in a water bath for 30 minutes, cooled and centrifuged. The supernatant (1.0 ml) was mixed with 2, 2-bipyridine ($C_{10}H_8N_2$) solution (1.5 ml) and the absorbance measured using spectrophotometer at 519 nm. The concentration of phytate was obtained by extrapolation from a standard curve prepared from standard phytic acid ($C_6H_{18}O_{24}P_6$) solution, and expressed in mg /100 g dry sample.

Statistical Analysis

Data were collected in duplicate, Analysis of Variance (ANOVA) and Dunnett t-test done using Statistical Package for Social Scientists (SPSS) version 20 at 5% probability level was used to assess significant mean difference (MD) between the control (fresh) and pretreatments. The results were presented in bar charts, tables, mean, standard deviation and coefficient of determination.

RESULTS AND DISCUSSION

Antioxidant Activity

The summary and multiple comparisons of antioxidant activity of fresh leaves with pretreated and dried leaves are presented in Table 1.

Table 1. Summary and multiple comparisons of mean value of antioxidant activity of *Justicia insularis* and *Jatropha tanjorensis* fresh leaves with their mean values at different pretreatments and drying temperatures

P	T (^{0}C)	TPC (mg GAE / g db)	DPPH (%)	CUPRAC(µ mol Trolox /g db)	FRAP(µmol $FeSO_4$ /g db)
		Justicia insularis			
FR		9.81 ± 0.03^{j}	29.20 ± 0.11^{a}	185 ± 8.49^{c}	260 ± 14.14^{d}
UB	40	8.62 ± 0.01^{a}	31.45 ± 0.35^{b}	212 ± 32.83^{d}	280 ± 7.07^{e}
	50	9.07 ± 0.03^{b}	32.25 ± 0.21^{c}	267 ± 4.24^{e}	308 ± 5.66^{f}
	60	8.47 ± 0.01^{c}	31.15 ± 0.07^{d}	280 ± 5.66^{f}	312 ± 2.83^{g}
BHW	40	9.94 ± 0.02^{d}	30.23 ± 0.08^{e}	345 ± 7.07^{g}	331 ± 4.24^{h}
	50	9.98 ± 0.04^{e}	34.70 ± 0.14^{f}	481 ± 2.83^{h}	355 ± 32.83^{i}
	60	8.65 ± 0.03^{f}	30.30 ± 0.21^{g}	492 ± 4.28^{i}	353 ± 4.24^{j}
BSW	40	8.29 ± 0.03^{g}	28.40 ± 0.04^{h}	181 ± 2.83^{c}	234 ± 1.41^{k}
	50	7.18 ± 0.01^{h}	27.60 ± 0.42^{i}	235 ± 1.48^{j}	247 ± 4.95^{d}
	60	7.16 ± 0.03^{i}	27.30 ± 0.28^{j}	223 ± 3.5^{k}	258 ± 2.47^{d}
		Jatropha tanjorensis			
FR		7.81 ± 0.03^{g}	18.25 ± 0.35^{a}	255 ± 5.66^{a}	311 ± 11.31^{c}
UB	40	7.35 ± 0.04^{a}	19.10 ± 0.14^{b}	379 ± 7.07^{b}	330 ± 4.24^{d}
	50	8.02 ± 0.08^{g}	20.20 ± 0.06^{c}	387 ± 2.83^{c}	340 ± 43.54^{e}
	60	7.89 ± 0.01^{g}	19.30 ± 0.04^{d}	383 ± 4.24^{d}	421 ± 1.41^{f}
BHW	40	8.96 ± 0.01^{b}	20.30 ± 0.01^{e}	398 ± 1.41^{e}	356 ± 4.95^{g}
	50	8.97 ± 0.02^{c}	22.40 ± 0.05^{f}	403 ± 4.24^{f}	444 ± 5.66^{h}
	60	9.97 ± 0.02^{d}	21.50 ± 0.14^{g}	412 ± 8.49^{g}	546 ± 2.83^{i}
BSW	40	7.75 ± 0.07^{g}	17.50 ± 0.07^{h}	269 ± 1.41^{a}	300 ± 2.83^{c}
	50	7.55 ± 0.16^{e}	17.80 ± 0.05^{i}	302 ± 2.12^{h}	410 ± 7.07^{j}
	60	6.97 ± 0.04^{f}	16.40 ± 0.06^{j}	293 ± 0.71^{i}	434 ± 1.41^{k}

Note: P=pretreatment, T=temperature (^{0}C), FR=fresh sample, UB = un-blanched and dried sample, BHW=sample blanched in hot water and dried, and BSW=sample blanched in salt water and dried. All data are the mean $\pm$ standard deviation of duplicate. Mean with the same superscript in the same column are statistically the same as the fresh sample (ANOVA, $P_{tab} < 0.05$, Dunnette t-test).

From Table 1., the fresh samples of *Justicia insularis* and *Jatropha tanjorensis* leaves contained 9.81 and 7.81 mg GAE / g db of total phenolic content (TPC), 29.20 and 18.25% of DPPH scavenging activity (DPPH), 185 and 255 µmoles Trolox / g db of CUPRAC, and 260 and 311 µmole $FeSO_4$ /g db of FRAP, respectively. The values for TPC were low when compared to values reported in literature for leafy vegetables [16], however, the DPPH was within range. These are just some of the ways in which each plant differs from each other, no two plants are exactly the same, even the same specie but different cultivars are different, hence need for characterization. The effects of each of the pretreatments used on this study the TPC are as follows:

There was increase with the BHW samples of up to about 1.73 and 1.325 % at 50 and 40 °C of drying temperature respectively, similar to reports of Bamide *et al.* [16]. This must have been due to the composition of the TPC of this plant.

Some phenolic compounds were seen to appreciate on blanching while some depreciate at varying degrees on blanching. Irondi *et al.*[32] reported that every other phenolic compound identified in their study depreciated during blanching but quercetin increased by 245 % and the least affected being the ellagic acid. Therefore, *Justicia insularis* may have been made of more of quercetin which may have been adversely affected at a higher temperature (60 °C) of drying. The increase in TPC may also be due to the release of the phenolic acids that were bound in the cell walls of the leaves. The pretreatment that affected TPC most adversely was the BSW, it shows the highest loss of about 27.01 % which may have been due to the fact that the salt solution may have reacted with the TPC to formed complex / other compounds making the TPC not available, making them sensitive to salt water. *Jatropha tanjorensis* followed a trend similar to that of *Justicia insularis*, with a maximum increase of 27.66% during BHW pretreatment and a highest loss of 10.76 % during BSW pretreatment. UB samples showed the least loss, this must have due to fact the degradation wasn't much prior to drying. The little loss during UB may have been due to the drying temperature. The effects of temperature on TPC are seen to be minimal at 50 °C, followed by 40 °C and maximum at 60 °C. The DPPH scavenging activity was seen to increase for both leaves (Table 1 and 2) during the UB and BHW and worst during BSW. The increase in DPPH activity does not agree with the studies of Irondi et al. [32]. Several studies have reported the loss of DPPH during blanching due to leaching which is logical. However, this present study shows that every plant is unique. Report [17] has that blanching time and drying temperature could either reduce or enhance antioxidant activity in dried vegetables depending on the vegetable. The highest increase of CUPRAC (492 µmoles Trolox /g) in dried *Justicia insularis* samples was obtained at BHW60 ^{0}C while the least increase (181 µmoles Trolox /g db) was obtained at BSW 40 ^{0}C. In the same vein, CUPRAC in dried *Jatropha tanjorensis* leaves at BSW 40 ^{0}C recorded the least increase (269 µmoles Trolox /g db) while the highest increase (412 µmoles Trolox /g db) was found at BHW60 ^{0}C. Apart from that, FRAP in both dried vegetables increased as the drying temperature increased from 40 ^{0}C to 60 ^{0}C except at BHW where the content increased to 331 µmole $FeSO_4$ /g db initially and reduced infinitesimally from 355 to 353 µmoles $FeSO_4$ /g db in dried *Justicia insularis* samples. The highest FRAP of 355 and 546 µmoles $FeSO_4$ /g db were obtained at BHW50 ^{0}C and BHW60 ^{0}C, while the least amount of 234 and 300 µmoles $FeSO_4$ /g db were found at BSW 40 ^{0}C, in both dried *Justicia insularis* and *Jatropha tanjorensis* leaves, respectively. Steam blanching of kaffir lime leaf was found to increase TPC and FRAP from 20.10 ± 0.14 to 22.18 ± 0.06 mg GAE / g and 447 ± 9.01 to 628 ± 27.02 µmole $FeSO_4$ /g (Ratseewo et al., 2016). Blanching of *Andrographis paniculata* and heat-pump dehumidified drying at 40 to 60^{0}C was observed to increase total phenolics [33]. Bamidele *et al.* [16] reported that 5 minutes blanching time was found to increase TPC of several vegetables (from 280.6 to 980.6 mg GAE / 100 g db) and other antioxidant activities (from 25.1 – 95.1 mg GAE / 100 g db). A combination of freeze/ microwave drying was observed to significantly increase the antioxidant activity (DPPH scavenging activity and FRAP) [13].

A study by Pierre et al., [20] showed an increase in total reducing power but decrease in DPPH scavenging activity of *Moringa oleifer* leaves after blanching and drying in an electric oven.

Polyphenol content and DPPH of gurum seed oil were found to increase from 22.6 to 25.3 mg GAE / kg oil and 59.2% to 64.7% after pretreatment, respectively [12]. The results of the present study are in line with similar reported studies [17, 34, 35].
However, by comparing both fresh leaves with pretreated and dried leaves, it is observed that all the mean values of TPC at different pretreatments and drying temperatures had statistical significant difference (P_{tab}< 0.05) for dried *Justicia insularis* leaves when compared with the fresh leaves. However, the pretreatment/ drying temperatures, for instance, UB50 ^{0}C and 60 ^{0}C and BSW 40 ^{0}C did not have any statistical significant difference on TPC when compared with the fresh leaves of *Jatropha tanjorensis* while the rest had statistical significant difference. Besides, all the mean values of DPPH in both vegetables had statistical significant mean differences. Furthermore, the mean values of CUPRAC in dried *Justicia insularis* and *Jatropha tanjorensis* leaves were not different from those ones obtained at BSW 40 ^{0}C. Conversely, the mean values of FRAP in dried *Justicia insularis* and *Jatropha tanjorensis* leaves were all different from their corresponding fresh contents except those obtained at BSW 50 ^{0}C and 60 ^{0}C, and BSW 40 ^{0}C.

Effect of Pretreatments and Drying Temperatures on Antioxidant Activity

The effects of pretreatments and drying temperatures on antioxidant activity of *Justicia insularis* and *Jatropha tanjorensis* leaves are given on Table 2.

Table 2. Summary of ANOVA results showing the effect of pretreatments and drying temperatures on antioxidant activity of *Justicia insularis* and *Jatropha tanjorensis* leaves

Sample Leaves	Antioxidant Activity	Sources of Variance	R^2	F-Value	Sig. (P_{cal})
Justicia insularis	TPC (mg GAE / g)	T	1.000	9060.7*	0.000
		P		1818.4*	0.000
		T × P		748.4*	0.000
	DPPH (%)	T	0.994	543.0*	0.000
		P		109.0*	0.000
		T × P		72.97*	0.000
	CUPRAC (µmoles Trolox /g)	T	0.999	5039.8*	0.000
		P		804.8*	0.000
		T × P		104.1*	0.000
	FRAP (µmoles $FeSO_4$ /g)	T	0.995	813.04*	0.000
		P		62.90*	0.000
		T × P		2.52	0.115
Jatropha tanjorensis	TPC (mg GAE / g)	T	0.997	1309.30*	0.000
		P		22.28*	0.000
		T × P		126.03*	0.000
	DPPH (%)	T	0.999	3983.70*	0.000
		P		379.96*	0.000
		T × P		113.74*	0.000
	CUPRAC (µmoles Trolox /g)	T	0.996	1190.81*	0.000
		P		21.76*	0.002
		T × P		7.01*	0.008
	FRAP (µmoles $FeSO_4$ /g)	T	0.998	691.02*	0.000
		P		1649.43*	0.000
		T × P		132.34*	0.000

Note: R^2 = coefficient of determination, F-value =variance ratio and P_{cal} = calculated value of probability distribution.

From Table 2, the overall effects of pretreatment (P) and drying temperature (T) on antioxidant activity of both dried vegetables is mostly notable with the values of R^2 between 0.994 – 1.000. The amount of distinctive influence of P and T revealed that P_{cal} < 0.05 for all the antioxidant activities examined in both vegetables. Thus, F-values were all statistically significant. The interactive effect of T × P on antioxidant activities in both vegetables was also significant, except FRAP in dried *Justicia insularis* samples with $P_{cal} = 0.115$.

Antinutrient Contents

The summary and multiple comparisons of antinutrient content of fresh leaves with pretreated and dried leaves are presented in Table 3.

Table 3.Summary and multiple comparisons of antinutrient content of fresh leaves with pretreated and dried leaves of both *Justicia insularis* and *Jatropha tanjorensis*

P	T	*Justicia insularis*				*Jatropha tanjorensis*			
		Oxalate (mg / 100 g db)	HCN (mg / 100 g db)	Tannin (mg / 100 g db)	Phytate (mg / 100 g db)	Oxalate (mg / 100 g db)	HCN (mg / 100 g db)	Tannin (mg / 100 g db)	Phytate (mg / 100 g db)
FR		0.22 ± 0.03^a	0.65 ± 0.04^b	2.11 ± 0.01^c	4.35 ± 0.04^d	0.18 ± 0.01^a	0.10 ± 0.01^c	1.19 ± 0.01^e	1.24 ± 0.04^a
UB	$40\ ^0C$	0.19 ± 0.04^a	0.62 ± 0.01^b	2.09 ± 0.02^c	4.22 ± 0.01^e	0.16 ± 0.03^a	0.08 ± 0.02^c	1.15 ± 0.03^e	1.11 ± 0.03^b
	$50\ ^0C$	0.17 ± 0.02^a	0.57 ± 0.03^c	2.04 ± 0.03^d	3.91 ± 0.01^f	0.14 ± 0.02^b	0.06 ± 0.03^c	1.13 ± 0.01^f	1.10 ± 0.01^c
	$60\ ^0C$	0.17 ± 0.01^a	0.45 ± 0.03^d	1.99 ± 0.03^e	4.01 ± 0.15^g	0.13 ± 0.01^c	0.04 ± 0.01^d	0.92 ± 0.01^g	0.99 ± 0.01^d
BHW	$40\ ^0C$	0.14 ± 0.02^b	0.41 ± 0.01^e	1.03 ± 0.01^f	3.33 ± 0.47^h	0.09 ± 0.01^d	0.08 ± 0.02^c	0.93 ± 0.02^h	0.86 ± 0.03^e
	$50\ ^0C$	0.09 ± 0.01^c	0.37 ± 0.02^f	1.02 ± 0.01^g	2.77 ± 0.07^i	0.07 ± 0.01^e	0.06 ± 0.03^c	1.03 ± 0.03^i	0.72 ± 0.02^f
	$60\ ^0C$	0.07 ± 0.03^d	0.34 ± 0.03^g	0.86 ± 0.04^h	2.70 ± 0.01^j	0.05 ± 0.02^f	0.05 ± 0.01^e	0.97 ± 0.03^j	0.63 ± 0.02^g
BSW	$40\ ^0C$	0.21 ± 0.01^a	0.44 ± 0.02^h	1.12 ± 0.03^i	3.51 ± 0.06^k	0.15 ± 0.04^a	0.07 ± 0.03^c	0.81 ± 0.01^k	0.93 ± 0.03^h
	$50\ ^0C$	0.18 ± 0.01^a	0.31 ± 0.01^i	0.89 ± 0.01^j	3.48 ± 0.08^l	0.11 ± 0.03^g	0.03 ± 0.01^f	0.76 ± 0.02^l	0.86 ± 0.03^i
	$60\ ^0C$	0.14 ± 0.02^e	0.33 ± 0.01^j	0.81 ± 0.03^k	2.98 ± 0.03^m	0.09 ± 0.02^h	0.05 ± 0.01^g	0.96 ± 0.01^m	0.85 ± 0.01^j

Note: P = pretreatment, T = temperature (^{0}C), FR= fresh sample, UB = un-blanched and dried sample, BHW = sample blanched in hot water and dried, and BSW = sample blanched in salt water and dried. All data are the mean ± standard deviation of duplicate. Mean with the same superscript in the same column are statistically the same as the fresh sample (ANOVA, $P_{tab} < 0.05$, Dunnett t-test).

From Table 3, the fresh samples of *Justicia insularis* and *Jatropha tanjorensis* leaves were found to be 0.22 and 0.18 mg / 100 g db of oxalate, 0.65 and 0.10 mg / 100 g db of HCN, 2.11 and 1.19 mg / 100 g db of tannin, and 4.35 and 1.24 mg /100 g db of phytate, respectively. Notably, the concentrations of all the antinutrients in *Justicia insularis* leaves were higher than that of *Jatropha tanjorensis* leaves and were also reduced at increased drying temperature from 40 ^{0}C to 60 ^{0}C. This study shows the reduction of antinutrients during all the pretreatment used in this study this is in agreement with some reported studies [36, 37, 14, 19, 38] while others reported of increase in antinutrients at higher temperatures [18, 39]. However, oxalate contents in the fresh *Justicia insularis* and *Jatropha tanjorensis* leaves were found to reduce to minimal contents of 0.07 mg / 100 g db and 0.05 mg / 100 g db, both at BHW60 ^{0}C, respectively. Similarly, BSW 50 ^{0}C produced the least HCN content of 0.31 and 0.03 mg / 100 g db for *Justicia insularis* and *Jatropha tanjorensis* leaves, respectively.

The minimum tannin contents of 0.81 and 0.76 mg / 100 g db were found at BSW60 ^{0}C and BSW50 ^{0}C for Justicia *insularis* and *Jatropha tanjorensis* leaves, respectively. The lowest phytate contents of 2.70 and 0.63 mg / 100 g db were obtained at BHW 60 ^{0}C for both *Justicia insularis* and *Jatropha tanjorensis* leaves, respectively. Generally, the reduction in antinutrients may be due to leaching during duration blanching. It was observed that BHW 60 ^{0}C favored reduction of oxalate and phytate contents while BSW50 ^{0}C drastically reduced HCN and tannin contents. However, by comparing both fresh leaves with pretreated and dried leaves, it is observed that the mean values of oxalate content of *Justicia insularis* leaves at BHW40 ^{0}C, BHW50 ^{0}C and BSW 60 ^{0}C were statistically different from that of the fresh sample at $P_{tab} < 0.05$ when compared while the rest with the same superscript in the same column did not have any statistical significant difference. Also, the mean value of oxalate content of fresh *Jatropha tanjorensis* leaves was not different from those ones obtained at UB 40 ^{0}C and BSW 40 ^{0}C. Similarly, the fresh HCN content of *Justicia insularis* leaves was the same as the one obtained at UB 40 ^{0}C. The rest showed statistical significant differences. However, all the mean values of HCN content of dried *Jatropha tanjorensis* leaves obtained at UB40 ^{0}C, UB50 ^{0}C, BHW40 ^{0}C, BHW50 ^{0}C and BSW40 ^{0}C were not significantly different from that of the fresh sample. Besides, the mean values of tannin content in dried *Justicia insularis* and *Jatropha tanjorensis* leaves obtained at UB40 ^{0}C were not different from their corresponding fresh contents while the rest recorded statistical significant mean differences. Furthermore, the mean values of phytate content in dried *Justicia insularis* and *Jatropha tanjorensis* leaves were all different from their corresponding fresh contents. It can be deduced that pretreatment and drying temperature could affect to some extent the antinutrients present in both vegetables under investigation.

Effect of Pretreatments and Drying Temperatures on Antinutrient Contents

The effects of pretreatments and drying temperatures on antinutrient contents of *Justicia insularis* and *Jatropha tanjorensis* leaves are given on Table 4 and Table 5.

Table 4. Summary of ANOVA results showing the effect of pretreatments and drying temperatures on antinutrient contents of *Justicia insularis leaves*

Sample Leaves	Antinutrient Content	Sources of Variance	R^2	F-Value	Sig. (P_{cal})
Justicia insularis	Oxalate (mg /100 g)	T	0.896	9.148*	0.007
		P		26.704*	0.000
		T × P		1.41	0.307
	HCN (mg /100 g)	T	0.979	47.54*	0.000
		P		152.54*	0.000
		T × P		7.10*	0.007
	Tannin (mg /100 g)	T	0.999	95.4*	0.000
		P		4083.4*	0.000
		T × P		17.69*	0.000
	Phytate (mg /100 g)	T	0.949	11.49*	0.003
		P		67.10*	0.000
		T × P		2.47	0.120

Table 5. Summary of ANOVA results showing the effect of pretreatments and drying temperatures on antinutrient contents of *Jatropha tanjorensis* leaves

Jatropha tanjorensis	Oxalate (mg /100 g)	T P T × P	0.826	5.86* 14.86* 0.29	0.023 0.001 0.876
	HCN (mg /100 g)	T P T × P	0.531	3.05 0.66 0.70	0.097 0.541 0.613
	Tannin (mg /100 g)	T P T × P	0.986	1.38 172.60* 67.60*	0.300 0.000 0.000
	Phytate (mg /100 g)	T P T × P	0.989	62.50* 327.84* 8.80*	0.000 0.000 0.004

From Table 4 and Table 5, the overall effect of pretreatment (P) and drying temperature (T) on antinutrients of both dried vegetables is judged by the values of R^2, which ranged from 0.531 to 0.999.

However, the gross effect of P and T on HCN content of *Jatropha tanjorensis* leaves was statistically insignificant, since $R^2 = 0.531$ (quite less than 1.00). This implies that the combination of P and T may likely have minute reduction in HCN content of dried *Jatropha tanjorensis* leaves. Besides, the amount of distinctive effect of P and T revealed that $P_{cal}<0.05$, thus, F-values were statistically significant for all the antinutrients examined in both vegetables except tannin and HCN contents in *Jatropha tanjorensis* leaves. This means that within the drying temperature of 40 ^{0}C - 60 ^{0}C, variation in tannin and HCN contents in *Jatropha tanjorensis* leaves may be infinitesimal. The interactive effect (T × P) on antinutrients in both vegetables was also significant, except oxalate and phytate contents in dried *Justicia insularis* samples and oxalate content in dried *Jatropha tanjorensis* leaves with $P_{cal} > 0.05$. It therefore means that pretreated samples using appropriate method and dried at optimum temperature could possibly reduce these antinutrients.

CONCLUSIONS

This study was carried out to evaluate the effects of processing temperature and pretreatments on antioxidant and antinutrient content of *Justicia insularis* and *Jatropha tanjorensis* leaves. BHW pretreatment between 50^0 C and 60^0 C was found to increase the antioxidant activity in both vegetables. BHW at 60 ^{0}C was able to reduce oxalate and phytate contents to minimal level while BSW at 50 ^{0}C drastically decreased HCN and tannin contents. However, the overall, individualistic, and interactive effects of P and T had significant ($P_{cal} < 0.05$) influence on majority of antioxidant activity and antinutrient contents in both vegetables.

It could therefore be concluded that Blanching *Justicia insularis* and *Jatropha tanjorensis* leaves using hot water at 95^{0}C for 2 mins and drying within the range of temperature in this study could possibly increase the antioxidant activity and also reduce antinutrients to some level.

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EFEKTI PREDTRETIRANJA I TEMPERATURE SUŠENJA NA ANTIOKSIDANTE I ANTINUTRIJENTE LISTA *Justicia insularis* I *Jatropha tanjorensis*

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Sažetak: Obrada posle berbe povrća može uticati na antioksidante i antinutrijente listova povrća. Ova studija sprovedena je da se proceni efekat predtretmana (P) i temperatura sušenja (T) na antioksidante i antinutrijente listova povrća *Justicia insularis* i *Jatropha tanjor*ensis. Pripremljene su četiri grupe uzoraka: sveži uzorak (FR), neblanširani i osušeni uzorak (UB), uzorak blanširan u vrućoj vodi i osušen (BHV) i uzorak blanširan u slanoj vodi i osušen (BSV).

Sušenje listova povrća je izvedeno na temperaturama od 40°C, 50°C i 60°C u peći sa toplim vazduhom. Određeni su sadržaji antioksidanta i antinutrijenta u uzorku. Prikupljeni podaci su analizirani dvostrukom Analizom varijanse (ANOVA), I Dunnett t-testom na nivou verovatnoće od 5%.

Na osnovu rezultata, BHV između 50°C i 60°C povećao je antioksidativnu aktivnost u oba varijeteta listova povrća. BHV na 60°C je imao manji sadržaj oksalata i fitata na razumni nivo, dok je BSV 50°C drastično smanjio sadržaj hidrogen cijanida i tanina . Međutim, ukupni, individualni i interaktivni efekti P i T imaju značajan (P_{cal} <0,05) uticaj na većinu antioksidativne aktivnosti i sadržaja antinutrijenata u oba ispitivana varijeteta povrća.

Ključne reči: *Justicia insularis, Jatropha tanjorensis, predtretman, temperatura sušenja, antioksidanti, antinutrijenti*

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HIDRAULIČKI AGREGATI U POLJOPRIVREDNOJ TEHNICI

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Sažetak: Uz odmeren pristup, prenos snage od nekog tipa pogonskog motora do radnih organa ili hodnih sistema različitih tipova mašina, ne mora predstavljati ozbiljan problem. U poljoprivrednoj tehnici, prenosu energije treba pažljivo pristupati, te primenjivati energetski prilagođena tehnička rešenja u većini izdvojenih slučajeva. Navedena rešenja moraju biti posebno usklađena sa dinamičkim energetskim potrebama sistema, koja treba da obezbede prenos energije koji je tehnički, tehnološki, ekonomski i ekološki usklađen sa teško predvidivim dinamičkim potrebama hidrauličkih agregata i sistema u poljoprivrednim radovima i primenjenoj mehanizaciji Ipak, primena hidrauličkog pogona ili bar njegovo učešće u prenosu snage, danas je postala skoro neizbežna praksa. To je posebno važno, ukoliko postoji i elektronska kontrola procesa prenosa snage. Tada se uz niz dodatnih prednosti, uključujući fleksibilnost hidrauličnih vodova, prenos energije od proizvoljnih tipova primarnih izvora i energetskih pretvarača, pa sve do odgovarajućih upravljačkih jedinica ili potrošača, može uspešno, efikasno i precizno ostvariti.

Ključne reči: *poljoprivreda, mehanizacija, snaga, prenos.*

UVOD

Hidraulički sistemi [1], se u značajnoj meri primenjuju u mašinskoj, građevinskoj i rudarskoj tehnici, poljoprivredi i hidrotehničkim melioracijama [12], drumskom i železničkom saobraćaju, vozilima posebne namene opremljenim različitim oružanim sistemima, energetici, aero-kosmo tehnici itd.

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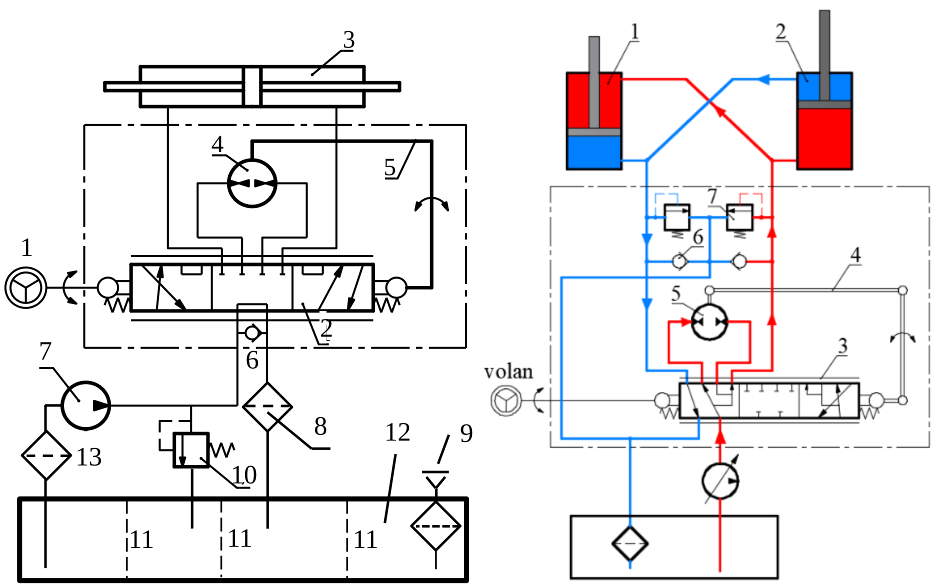
Svaki od ovih navedenih sistema može biti sačinjen od najrazličitijih hidrauličkih komponenata, namenjenih za regulaciju, nadzor procesa, prenos energije, merenja i obavljanje raznih drugih upravljačkih i izvršnih funkcija. Od njih se sastavljaju razne konfiguracije funkcionalno povezanih radnih celina, radi izvršavanja jednog ili istovremeno više radnih zadataka [2]. Navedene komponente se isporučuju kao pojedinačni elementi, ili kao već fabrički grupisani elementi u manju ili veću funkcionalnu grupu (celinu).

U ovom tekstu su prikazane neke od mnogih mogućnosti primene savremene hidraulike u izrazito teškim uslovima rada moderne poljoprivredne mehanizacije.

UPRAVLJANJE PRAVCEM KRETANJA TRAKTORA SA TOČKOVIMA



(a) (b)

Slika 1. Hidraulička šema agregata za upravljanje sa točkovima traktora: a) Parker Hydraulics [3], 1-upravljački točak, 2-proporcionalni servo razvodni ventil, 7-pumpa, 3-cilindar dvosmernog dejstva, 4-pumpa/motor, 5-mehanička veza pumpe/motora i razvodnog ventila, 6-rezervoar, 10-sigurnosni ventil, 8-fini filter ulja, 9-usisni otvor, 12-grubi filter, 11-mrežice za smanjenje pojave pene u rezerevoaru, 13-glavni usisisni filter pumpe. b) Case Maksum [4]: 1-cilindar za usmeravanje točkova u levo, 2-cilindar za usmeravanje točkova u desno, 3-proporcionalni razvodni ventil, 4-mehanička veza pumpe/motora i razvodnog ventila, 5-pumpa/motor, 6-nepovratni ventili, 7-sigurnosni ventili.

Figure 1. Hydraulic schema of the tractor steering aggregate: a) Parker Hydraulics [3], 1-steering wheel, 2-directional control valve, 7-pump, 3-double acting cylinder, 4-pump/motor, 5-mechanical conection between pump/motor and proportional valve, 6-rezervoir, 10-relief valve 8-fine oil filter, 9- oil inlet openining and cap, 12-crude oil filter, 11-nets, 13-mail suction oil filter; b) Case Maksum [4]: 1-cylinder for left turning of the steering wheels, 2-cylinder for right turning of the steering wheels, 3-spool proportional valve, 4-mechanical connextion between the pump/motor and proportional valve, 5-pump/motor, 6-check valves, 7-relief valves.

Hidraulički agregat, koji se primenjuje u sastavu hidrauličkog upravljačkog sistema (za izbor i podešavanje pravca kretanja) nekih tipova savremenih traktora, izrađuje se često u jednoj od dve verzije. U jednoj varijanti, nakon prestanka zakretanja točkova dolazi do njihovog vraćanja u centralni položaj, koji odgovara pravolinijskom kretanju mašine. U drugoj verziji točkovi ostaju u zakrenutom položaju pa traktor nastavlja krivolinijsko kretanje zadato položajem upravljača.

Prvi tip agregata [3], slika 1(a), sadrži upravljač (1) i obrtni servo razvodni ventil (2). Ovaj ventil reguliše pritisak i usmerava kretanje ulja od pumpe (7) prema cilindru (3) koji je povezan sa mehanizmom zakretanja točkova traktora. U upravljački agregat je ugrađen i pumpa/motor dvostranog dejstva (4), čiji zadatak je da pošalje potrebnu količinu hidrauličnog ulja prema strani cilindra koja je u sinhronizaciji sa komandom zadatom upravljačem (volan). Pumpa/motor je mehanički kruto povezan/a (5) sa obrtnim servo razvodnim ventilom (1), tako da je pomeranje navedenog ventila (odgovarajuća pozicija) u potpunosti sinhronizovano sa smerom obrtanja rotora hidrauličke pumpe/motora.

Za kompletiranje hidrauličkog sistema upravljanja pravcem kretanja traktora, pored agregata, prikazanog na slici 1(a), označenog sa linijom tipa crta-tačka-crta, potrebno je dodati pumpu (7), rezervoar (6), sigurnosni ventil (7), filter ulja (8) i hidraulički radni cilndar sa klipom (3).

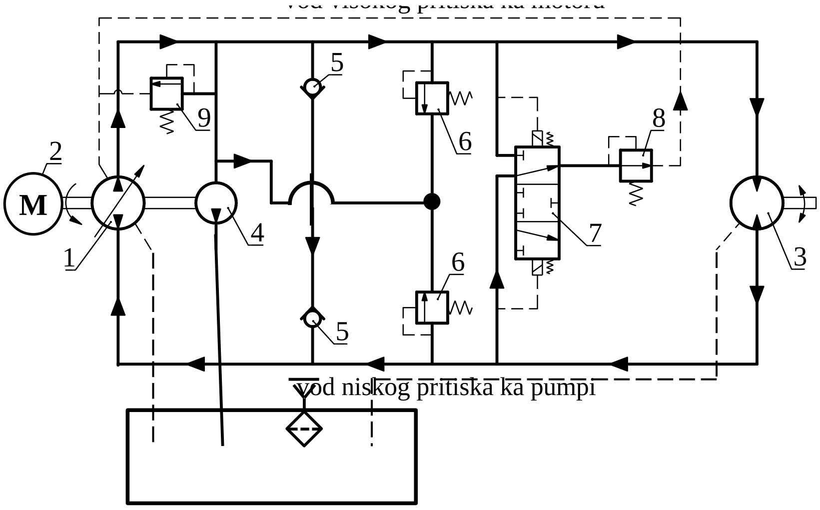
Agregat iste namene, ali različite konstrukcije i operativnih osobina [4], prikazan je na slici 1(b). Upravljačku funkciju ostvaruje povezivanjem sa dva izvršna organa, čiju funkciju obavljaju hidraulički radni cilindri dvostranog dejstva (1) i (2). Jedan od njih usmerava točkove u levo (1), a drugi u desno (2). U navedeni hidraulički agregat je ugrađen proporcionalni razvodni ventil (3), koji je mehanički povezan (4) sa zupčastom [5] "gerotor", pumpom (5). Time je obezbeđena sinhronizacija obe hidrauličke komponente sa zakretanjem točka upravljača. Odgovarajuće zakretanje upravljača dovodi razvodnik u poziciju usmeravanja toka hidrauličnog hidraulično ulja prema zupčastoj "gerotor" komponenti u smeru kazaljke na satu, a ona ga zatim potiskuje prema desnom vodu u cilju podizanja desnog klipa. Obrnuti smer obrtanja točka upravljača pomera razvodni ventil u drugu poziciju i usmerava hidraulično ulje prema "gerotoru" suprotno kazaljki na satu, koji potiskuje hidraulično ulje dalje ka levom cilindru radi podizanja njegovog klipa. U ovaj agregat su ugrađeni i nepovratni ventili (6) i sigurnosni ventili (7).

PRENOS SNAGE

U primeru (slika 2), prikazan je agregat [6] za prenos snage sa hidrauličke pumpe na hidraulički motor, koji zatim predaje snagu krajnjem potrošaču. Pumpa (1) dobija snagu od motora SUS ili elektromotora (2). Učestanost okretanja hidrauličkog motora se može regulisati uz pomoć prigušnog ili regulacionog ventila, ("load sensing") sistema sa sekundarnom regulacijom prtiska/protoka ulja, ili motori mogu imati ugrađene regulatore. U ovom primeru je primenjena pumpa promenljivog protoka sa ugrađenim regulatorom, tako da promena protoka pumpe izaziva promenu učestanosti rotiranja hidrauličkog motora (3). Kako je to glavna pumpa, po pravilu većeg protoka i pritiska, obično se za ove namene primenjuje klipna pumpa.

Izlazno vratilo hidrauličkog motora može se obrtati u oba smera. Time se omogućava i dvosmerno obrtanje vratila pripadajućeg izvršnog organa.

U skladu sa osnovnim principima mehanike fluida, cevovod kojim protiče hidrauličko ulje od pumpe prema motoru je pod visokim pritiskom, a hidraulično ulje u povratnom vodu je izloženo niskom pritisku. Međutim, pri reverzibilnom strujanju, u suprotnom smeru od potrošača prema pumpi, menja se uloga potisnog i povratnog voda, kao i smer obrtanja vratila pumpe i motora. Pomoću regulatora pumpe se pomera njena zakretna ploča, pa podešava smer i učestanost obrtanja izlaznog vratila hidrauličkog motora.



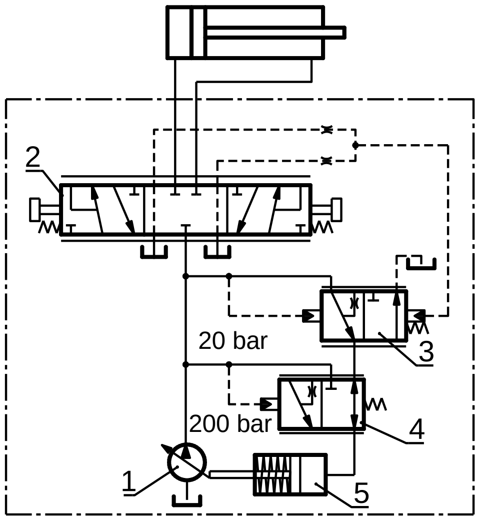
Slika 2. Hidraulička šema upravljanja sa hidrauličkim motorom [6]: 1-pumpa promenljivog protoka, 2-pogonski SUS motor ili elektromotor, 3-hidraulički motor dvostranog dejstva i konstantnog protoka, 4-ispirajuća pumpa niskog pritiska, 5-nepovratni ventili, 6-sigurnosni ventili, 7-razvodnik, 8-regulator pritiska, 9-sigurnosni ventil.

Figure 2. A scketch showing the hydraulic control system with hydraulic motor [6]: 1-variable displacement pump, 2-power supply engine, internal combustion type or electrical, 3- fixed displacement hydraulic motor, 4- small pressure and fixed displacement draining pump, 5-check valves, 6-relief valves, 7-directional control valve, 8-pressure regulator, 9-relief valve.

U ovaj opisan zatvoreni kružni tok se postavlja i druga pumpa (4). Ona može biti manjeg kapaciteta, tako da je najčešće zupčastog tipa. Zbog svoje uloge naziva se ispirajuća pumpa, jer obezbeđuje dovoljnu količinu hidrauličnog ulja u slučaju curenja oko 10% protoka glavne pumpe izmeni i šalje na hlađenje. Glavnu pumpu obezbeđuje od pojave kavitacije, a obavlja i proces podmazivanja.

U sistem su postavljeni i nepovratni ventili (5) za napajanje potisnog voda i dva ventila za ograničenje pritiska (6), slika 2, [6]. Razvodni ventil (7) prihvata iz potisnog voda predviđenih 10% od protoka glavne pumpe i šalje ga kroz ventil sigurnosti (8), čiji je pritisak podešen na pritisak u povratnom vodu. Hidraulično ulje se hladi i vraća u rezervoar glavne pumpe. U neutralnom položaju regulatora pumpe motor miruje, a otvara se sigurnosni ventil ispirajuće pumpe (9) koji šalje hidraulično ulje prema glavnoj pumpi sve dok je razvodnik u neutralnoj poziciji. Kada potrošač(i) preoptereti(e) motor, nastaje preveliki pritisak u usisnom vodu. Tada se otvara najbliži sigurnosni ventil (6), koji hidraulično ulje šalje kroz nepovratni ventil u potisni vod i prekida dotok ulja prema hidrauličkom motoru.

U cilju povećanja energetske efikasnosti, kompanija John Deere je za traktore razvila hidraulički regulator snage (RS), [7]. Primarne komponente ovog regulatora su pumpa promenljivog protoka i ventil za regulaciju pritiska i protoka, sa zadatkom da parametre hidrauličnog ulja usklade sa potrebama hidrauličkog motora. Agregat se primenjuje i kod drugih teških mašina, a može sadržati i razvodni ventil i/ili pomoćnu pumpu.



Slika 3. Hidraulička šema RS agregata u poziciji niskog pritiska, [7]: 1-pumpa, 2-proporcionalni razvodni ventil, 3-ventil za regulaciju protoka, 4-ventil za regulaciju pritiska, 5-regulacioni cilindar.

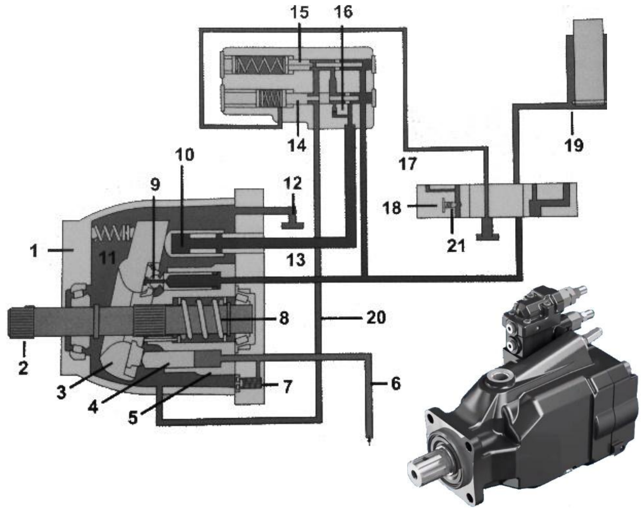
Figure 3. Hydraulic sketch of load sensing aggregate in the low pressure stend by mode [7]: 1-variable-displacement pump, 2-directional control valve, 3-flow regulator valve, 4- pressure regulator valve, 5-control cylinder.

Uključenjem pumpe (1) počinje protok hidrauličnog ulja niskog pritiska (oko 20 bar u datom primeru), slika 3, [7]. Ukoliko potrošač nije aktivan, odnosno razvodni ventil (2) je u neutralnom položaju, tada se fluid preko regulacionog ventila protoka (3) i regulacionog ventila pritiska (4) usmerava u regulacioni cilindar (5). Hidraulično ulje pomera klip cilindra koji postavlja pumpu u stanje minimalnog protoka. Signalni vod je povezan sa rezervoarom.

Slika 4a, prikazuje funkcionalnu šemu [8], kada je razvodnik (18) u neutralnom položaju. Signalni vod (17) koji upravlja radom regulacionog ventila protoka (14) je priključen na rezervoar. Aksijalna klipna pumpa (1) potiskuje hidraulično ulje kroz cevod (13). Razvodnik ne dozvoljava protok prema potrošaču već samo prema regulacionom ventilu (14). Razlika pritisaka između potisnog i povratnog voda prema rezervoaru pomera klip ventila otvarajući cevovod za protok hidrauličnog ulja prema klipu (10). Klip pomera zakretnu ploču (3) ventila dovodeći ga u položaj u kome je protok hidrauličnog ulja minimalan, sa podešenim pritiskom od 20 bar u prikazanom primeru. Na slici 4b prikazan je spoljni izgled razvodnika.

Aktiviranje pripadajućih potrošača ostvaruje se pomeranjem proporcionalnog razvodnog ventila u desno, kako što je šematski ilustrovano na slici 5.

Hidraulično ulje niskog pritiska (u ovom slučaju 20 bar) struji signalnim vodom prema regulacionom ventilu protoka, što dovodi do pomeranja klipa regulacionog ventila i zauzimanja novog položaja. U novom položaju razvodnika, hidraulično ulje iz regulacionog cilindra se usmerava prema prelivnom vodu i klip se pomera u desno, što rasterećuje zakretnu ploču aksijalne klipne pumpe i povećava protok pumpe. U razvodnom ventilu dolazi i do prigušenja pritiska hidrauličnog ulja kako bi pritisak na klipu cilindra bio za 20 do 30 bar niži od pritiska na izlazu iz pumpe. Time se postiže bolja regulacija brzine pomeranja klipa cilindra.

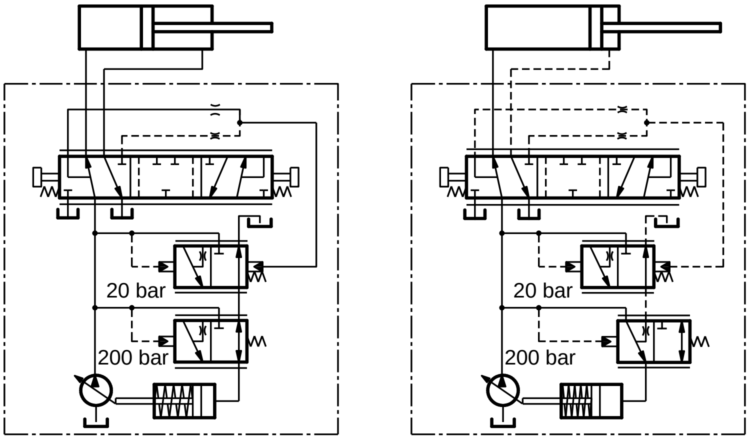


(a) (b)

Slika 4 [8]: Hidraulički „load sensing“ regulator CASAPPA LVP LC: (a) funkcionalna šema RS agregata sa radnim cilindrom u poziciji niskog pritiska: 1-kućište pumpe, 2-pogonsko vratilo, 3-zakretna klizna ploča, 4-klipovi, 5-rotirajuće telo, 6-dovod ulja od pumpe za napajanje, 7-ventil za nadpunjenje, 8-opruga za priljubljivanje klizne ploče, 9-otvor za podmazivanje klizne ploče, 10-hidraulički cilindar sa klipom za podešavanje položaja zakretne klizne ploče, 11-opruga za predna-prezanje zakretne klizne ploče, 12-povratni vod ka rezervoaru ulja, 13-vod za ulje pod pritiskom, 14-ventil za regulaciju protoka pumpe, 15-ventil za regulaciju maksimalnog pritiska, 16-nepovratni ventil, 17-signalni vod, 18-razvodnik, 19-radni cilindar, 20-vod prelivnog ulja, 21-podesiva prigušnica upravljačkog uređaja, b) spoljni izgled hidrauličkog agregata.

Figure 4 [8]: Hydraulic „load sensing“ regulator CASAPPA LVP LC: a) functional hydraulic scheme of load sensing aggregate in low pressure condition of load cylinder: 1-pump housing, 2-drive shaft, 3-swash plate, 4-axial pistons, 5-rotating group, 6-inlet from charge pump, 7-case fill and bleed valve, 8-spring hold down, 10-control piston, 11-bias spring ,12- flow line to reservoir, 13-out line high pressure flow, 14-flow control spool, 15-pressure compensator, 16-check valve, 17-control line, 18-directional control valve, 19-load cylinder, 20- bypass line, 21-adjustable restrictor, b) external view of load sensing aggregate.

Postizanjem maksimalnog pritiska u sistemu (u ovom primeru 200 bar, ali su dostupni i za veće pritiske do 400 bar) otvara se ventil regulacije pritiska i propušta hidraulično ulje prema regulacionom cilindru. Klip cilindra pomera zakretnu ploču u položaj koji dovodi do prekida protoka. Maksimalni pritisak se postiže i zaustavljanjem klipa radnog cilindra u krajnjem položaju.



(a) (b)

Slika 5. Hidraulička šema RS agregata u toku rada potrošača (a) i prilikom postizanja maksimalnog pritiska (b), [8].

Figure 5. Hydraulic schema of load sensing aggregate in the load mode (a) and in the high pressure stand by mode (b), [8].

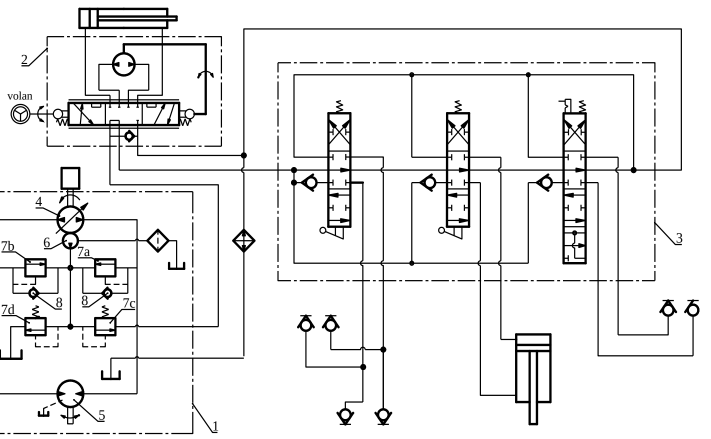
Proporcionalni razvodni ventil može biti sa elektomagnetnim upravljanjem (regulacijom). Impulsi ispred i iza razvodnog ventila se vode u električni pretvarač koji ih upoređuje i šalje električni signal prema razvodnom ventilu. On se u skladu sa signalom pomera u odgovarajući položaj takođe obezbeđujući razliku pritisaka oko 20 bar ispred i iza ventila.

HIDRAULIČKI SISTEM TRAKTORA JD 430

Hidraulički sistem traktora JD 430 [9], obavlja tri osnovne funkcije: transmisiju (1), usmeravanje upravljačkih točkova (2), obezbeđenje potrebne energije i pokretanje priključnih uređaja (3), kako je prikazano na slici 6.

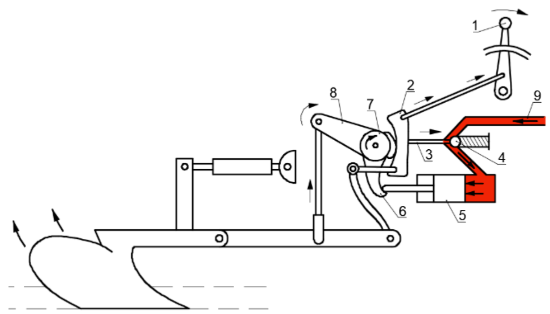
Glavna klipno-aksijalna pumpa hidrauličkog agregata za transmisiju (4) prima snagu od motora SUS direktno preko vratila. Dvosmerna je i promenljiivog protoka, kako bi se omogućila promena brzine i kretanje traktora unazad (respektivno). Njen zadatak je da snabdeva hidrauličnim uljem visokog pritiska hidraulički motor (5), koji pokreće ulazno vratilo višestepenog zupčastog prenosnika snage za redukciju učestanosti obrtanja pogonskih točkova. Hidraulički sistem je zatvorenog tipa.

U hidraulički agregat za transmisiju (prenos snage) (1) je ugrađena i zupčasta “gerotor” pumpa (6), radnog pritiska 6 do 12 bar. Ona ima dve osnovne funkcije: obezbeđuje dovoljnu količinu hidrauličnog ulja u agregatu i potiskuje ga prema agregatu za podešavanje pravca upravljačkih točkova traktora i ostalim potrošačima. U isti agregat su postavljeni i dva nepovratna (8) i dva sigurnosna ventila (7c,d). Hidraulično ulje iz pumpe (6), preko nepovratnog ventila, potiskuje se u usisni vod i time obezbeđuje dovoljnu količinu hidrauličnog ulja u agregatu transmisije i za podmazivanje komponenti sistema.



Slika 6. Hidraulički sistem traktora John Deere 430, [9]: 1-agregat transmisije, 2-agregat za upravljanja točkovima, 3-agregat prenosa energije prema priključcima, 4-dvosmerna klipno-aksijalna pumpa, 5-dvosmerni hidraulički motor, 6-pumpa za ispiranje, 7-sigurnosni ventili, 8-nepovratni ventili.

Figure 6. Hydraulic system of John Deere tractor 430, [9]: 1-transmission aggregate, 2-steering wheel aggregate, 3-aggregate suppluing energy to attachments, 4-bi-directional aksial-piston pump, 5- bi-directional hydrostatic motor, 6-charge pump, 7a,b,c,d- relief valves, 8-check valves



Slika 7. Podešavanje položaja pluga, [7]: 1-kontrolna ručica, 2- profilisana poluga, 3- poluga za otvaranje ventila, 4-loptasti ventil, 5-klip cilindra, 6-zakretač bregaste osovine, 7-bregasta osovina, 8-podizna ramena poluga, 9-hidrauličko ulje – dovod visokog pritiska iz pumpe

Figure 7. Plow control [7]: 1-control lever, 2-cam follower, 3-operating rod, 4-ball valve, 5-piston, 6-shaft arm, 7-rockshaft, 8-lift arm, 9-hydraulic oil – high pressure supply from pump

Hidraulično ulje koje se potiskuje prema agregatu za upravljanje točkovima, ima svoj sigurnosni ventil (7c). Sigurnosni ventil (7d), za obezbeđenje zupčaste pumpe, povezan je sa rezervoarom. Sigurnosni ventili (7a ili 7b) se otvaraju kada pritisak u potisnom vodu prelazi dozvoljenu vrednost, kada usmeravaju ulje kroz nepovratni ventil prema usisnom vodu.

Mehanizam za povezivanje priključnih oruđa (engl. attachemntes) sa pogonskim traktorom u tri tačke (engl. the three hitch point mechanism) je jedan izuzetno važnih potrošača energije hidrauličnog sistema traktora.

Ilustrativno, (slika 7), prikazana je uprošćena hidrauličko-mehanička funkcionalna šema sistema za podešavanje položaja pluga u cilju ostvarivanja određene-kontroliosane dubine oranja.

Navedeni priključni mehanizam može obavljati više zadataka. Podešavanje dubine oranja je samo jedan od njih: može biti automatsko ili ručno. Prikazani hidrauličko-mehanički mehanizam, (slika 7), zahteva ručnu kontrolu vertikalnog položaja pluga - dubine oranja. U tom slučaju, kada plug u toku oranja zemljišta bude izložen povećanom otporu (npr. usled nailaska plužnog tela na kamen), potrebno je da operator pomeri ručicu (1) napred u smeru prema slici 7. Pri tome, komandna ručica pomera profilisanu polugu (2) i polugu (3). Pomeranjem poluge (3) u smeru označenom na slici, otvara se ventil (4) i cevovod za protoka ulja viskog pritiska (9) prema cilindru (5). Ulje visokog pritiska potiskuje klip cilindra (5), kojim se zakreće osovina (7) u smeru podizanja gornje ramene poluge (8) i donje podizne poluge pluga, čime se plug vertikalno izdiže iz mase zemljišta, i obezbeđuje od pojave mogućeg oštećenja.

NOŠENA TRAKTORSKA PRSKALICA

Nošena traktorska prskalica (slika 8), čija je hidraulička šema prikazana na slici 9, namenjena je funkciji operacije kod zaštite ratarskih poljoprivrednih kultura.

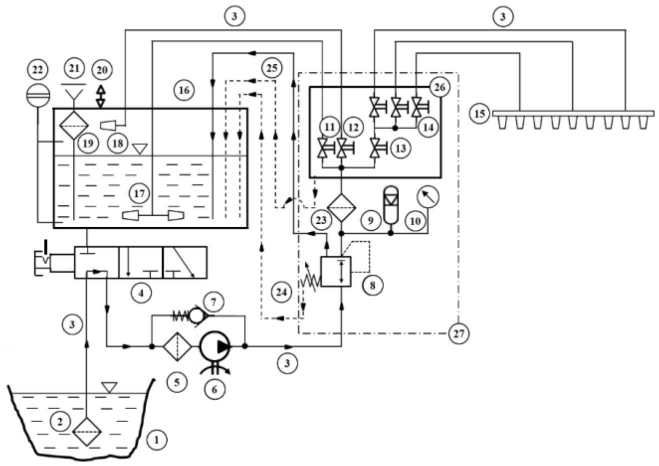
Slika 8. Nošena traktorska prskalica, [10].
Figure 8. Tractor mounted sprayer, [10].

Prema slici 9, iz raspoloživog izvora (1) se može, preko usisne korpe i filtera (2), obezbediti napajanje vodom za potrebe sistema. Voda se kroz cevovod (3) dovodi u razvodni ventil (4) na kome se podešava jedan od tri položaja koji određuje režim rada: usisni režim (slika 9a), režim pražnjenja (slika 9b) i režim prskanja (slika 9c). U režimu punjenja voda iz razvodnika, preko filtera (5), dospeva u pumpu (6). Nepovratni ventil (7) sprečava povratni tok vode. Iz pumpe se voda potiskuje kroz redosledni ventil (8) do potisnog voda (23), kojim se napaja glavni rezervoar (16). U rezervoar se sipa pesticid kroz nalivni otvor sa mrežnim filterom u obliku sita (21).

Poboljšanje mešanja pesticida sa vodom obavljaju rasprskivači mešača (17). Protok kroz njih se zatvara ventilom (11). Nivo napunjenosti rezervoara se kontroliše pokazivačem nivoa tečnosti (22).

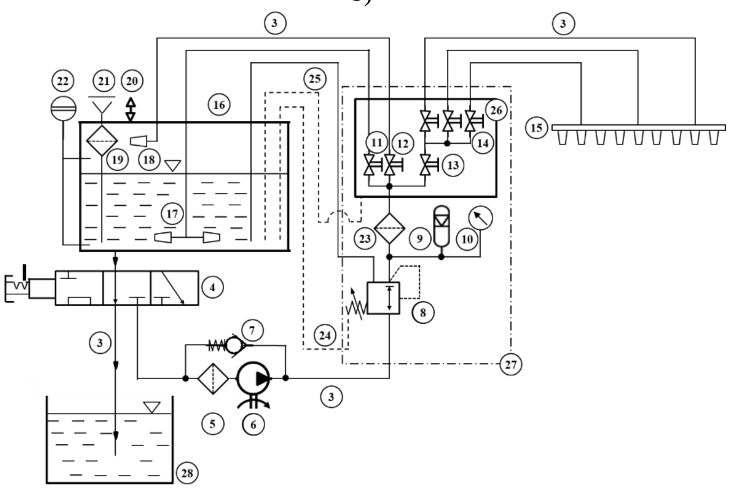
U režimu pražnjenja prskalice (slika 9b.), razvodni ventil (4) je u centralnom položaju, kada omogućava prelaz tečnosti iz glavnog rezervoara u kontejner (28).

Za potrebe prskanja se razvodni ventil postavlja u desni položaj (slika 9c.), da propusti rastvor iz glavnog rezervoara prema rasprskivačima (15).



a)

b)



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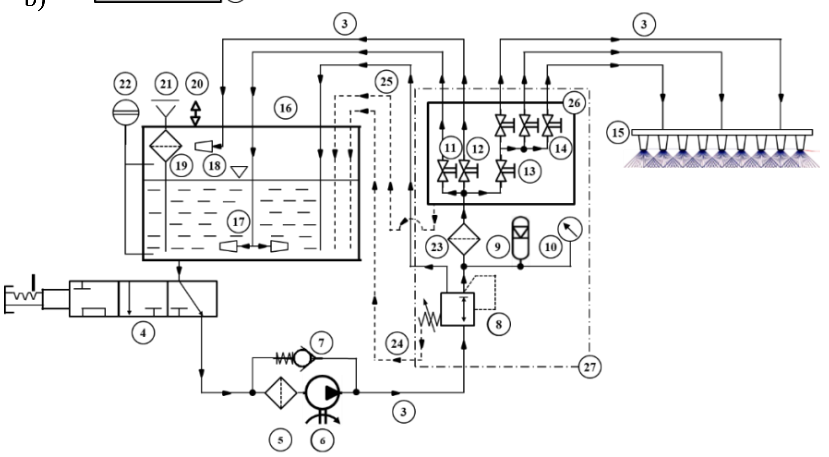


c)

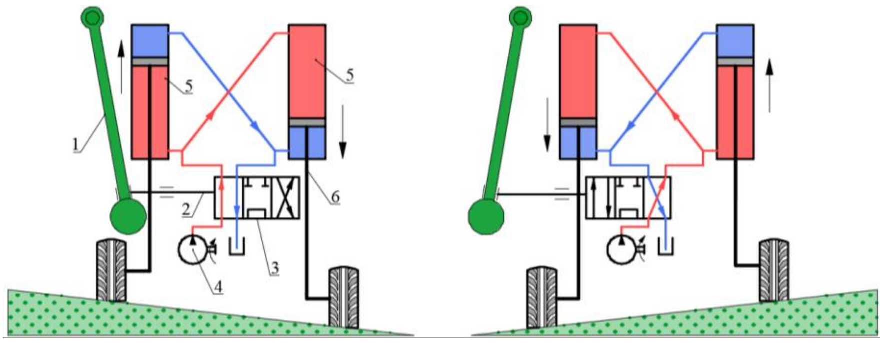
Slika 9. Hidraulički sistem nošene traktorske prskalice:1-izvor vode, 2-filter, 3-cevovod, 4- manuelni razvodnik sa tri položaja, 5-filter, 6-pumpa, 7-nepovratni ventil, 8-regulacioni ventil, 9- hidraulički akumulator, 10- merač pritiska, 11-zatvarački ventil za mešač, 12-zatvarački ventil za ispirač, 13-glavni zatvarački ventil, 14- zatvarački ventil za sekvencijalno napajanje rasprskivača, 15-rasprskivači zaštitnog sredstva, 16-glavni rezervoar, 17-mešač sa dva rasprskivača, 18-mlaznica za ispiranje, 19-filter, 20-odzračivač, 21-nalivno sito, 22- pokazatelj nivoa, 23-vod za punjenje rezervoara vodom, 24-prelivni vod, 25-prelivni vod za kapanje, 26-grupni zatvarački ventili, 27 agregat, 28-kontejner.

Figure 9. Hydraulic system of tractor maunted sprayer: 1-water source, 2-filter, 3-pipeline, 4-manual directional control valve (3 positions), 5-filter, 6-pump, 7-check valve, 8-pressure regulator, 9-hydraulic accumulator, 10-pressure gauge, 11-mixer shut-off valve, 12-rinse shut-off valve, 13-central shut off valve, 14-shut off valve for sequential spraying, 15-nozzles, 16-main reservoir, 17-mixer with two nozzles, 18- rinsing nozzle, 19-filter, 20-air vent, 22-level indicator, 23-water tank filling pipeline, 24-overflow pipeline, 25-dripping overflow line, 26-grouped shut-off valves, 27-aggregate, 28-container.

Zatvarački ventili (13) i (14) moraju biti u otvorenom položaju. Regulacioni ventil (8) održava stalan pritisak u potisnom vodu prema rasprskivačima.

Kao pomoć u održavanju stalnog pritiska, koji se meri mernim uređajem (10), postavlja se akumulator (9). Akumulator je podešen da se otvori kada dođe do pada pritiska. Za potrebe čišćenja i ispiranja postavlja se rasprskivač (18). Protok kroz rasprskivač, zaustavlja ventil (12).

NIVELACIJA POLOŽAJA ŠASIJE BERAČA JAGODASTOG VOĆA



Slika 10. Hidraulički sistem bočne nivelacije berača maline Elektronik [11]: 1-klatno, 2-poluga, 3-razvodni ventil, 4-pumpa, 5-cilindri, 6-klipnjača.

Figure 10. Hydraulic system for lateral leveling of the harvester of Company Elektronik [11]: 1-pemdulum, 2-lever, 3-directional control valve, 4-pump, 5-cylinders, 6-connectin rod.

Uzgoj jagodastog voća u se u velikoj meri obavlja na nagnutim terenima, zbog čega je automatska nivelacija položaja šasije primenjenih berača od posebne važnosti. Jednostavan i istovremeno pouzdan pristup rešenju ovog problema [11], primenjen je kod berača kompanije Elektronik (Sopot, Beograd).

Primarnu informaciju i upravljački signal za nivelaciju šasije kombajna na bočno nagnutom terenu omogućuje klatno (1).
Promene položaja klatna, u zavisnosti od nagiba terena, prenose se pomoću poluge (2) na hidraulički razvodnik (3) i postavljaju ga u odgovarajući položaj za hidrauličko podešavanje horizontalnog položaja šasije.

Pri odstupanju položaja šasije od horizontalnog, otvara se cevovod za prolaz ulja koju potiskuje pumpa (4) prema cilindrima (5). U cilindrima (5) se pomera klip sa klipnjačom (6), tako da točkovi berača prate nagib terena. Zahvaljujući tome, šasija mašine zadržava horizontalni položaj. Na slici 10 su prikazani položaji klatna i razvodnika za pozitivan i negativan nagib terena (u skladu sa matematičkom notacijom).

ZAKLJUČAK

Savremena poljoprivredna tehnika zavisi od intenzivne podrške efikasnih hidrauličkih sistema, sa korišćenjem precizne elektronske kontrole praktično svih procesa od interesa i tesnom spregom sa mehaničkim transmisionim elementima za prenos snage i upravljanja [12].

Treba očekivati da se ovakva praksa i dalje ne samo nastavi, nego i dalje unapredi, posebno u okviru razvoja univerzalnih samohodnih šasija [13-14].

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HYDRAULIC AGGREGATES IN AGRICULTURAL ENGINEERING

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Abstract: With an extremely carefully and very dedicated approach, power transmission may, but not obligatory, present a serious technical, environmental or econometric problem. In agricultural engineering, this process is unfortunately often further complicated. Therefore, energy transfer in this particularly sensitive area must be performmed with special care, and energy-specific technical solutions must be applied in each isolated case. These solutions must be specially harmonized with the dynamic energy needs of the system, and should provide energy transfer that is technically, technologically, economically and ecologically harmonized with the practically unpredictable dynamic needs of hydraulic elements and systems in agricultural engineering. However, the use of hydraulic drive, or at least its participation in power transmission, has become an almost inevitable practice today. This is especially important if it is also electronically controlled, because with a number of additional advantages including fluid line flexibility, energy transfer from arbitrary types of primary sources and energy converters, all the way to the appropriate control units or consumers can be achieved successfully, efficiently and accurately.

Key words*: agriculture, mechanization, power, transmission*

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