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DESIGN OF IRRIGATION SCHEME FOR AN IMPROVED FODDER CROP PRODUCTION AS FOOD FOR RANCH CATTLE

The object of this research is Cattle Ranches. Cattle Ranches is the practice of raising herds of cattle on large landscape including the structures and crops of legumes, grasses or forages, devoted to the raising, and grazing of the herds. Organized animal productions have been successfully practiced for decades in developed countries, but have been of minor Agricultural consideration in arid regions and Sub-Saharan Africa. Most African herders relied on natural pasture in the tropics which are either forested with high incidences of disease and parasites detrimental to profitable animal production, or dry zone which calls for tremendous physical exertion on the animal in order to obtain feed and water. Feed shortage and low quality of available feeds are constraints for livestock production and has been a major constraint for animal production during dry periods. Therefore, farmers use different coping mechanisms ranging from purchasing of feeds from the market and destocking unproductive animals as drastic measures. The negative trend results into many pastoralists resorting to grazing in crops farm lands. The pressure from increasing population and diminishing availability of land for pastoral range practice causes farmers- herders' clashes which results into loss of lives. Rise in the toll of farmers-herdsmen crisis and clashes across many African countries in recent years, became worst. This brings to fore, the need to set up Cattle Ranches as an alternative to nomadic agriculture. The viability of setting up ranches for Cattles using improved irrigation systems to make up for the dry zone/season condition is practicable and profitable as practiced in developed countries. Ranches provide feed from grown forage legumes and fodder trees species through irrigation, combined with appropriate postharvest handling practices. Feeds availability mitigate the constraints of food scarcity and improves livestock productivity. The study consisted of outlining design procedure for the establishment of an irrigation scheme for an improved fodder crop production as food for ranch cattle.

Keywords: *animal production, feed shortage, cattle ranch, improved irrigation systems, fodder crops.*

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1. Introduction

Livestock Agricultural systems have the ability to utilize pasture to produce saleable meat and milk. In Arid Regions, poor, extensive pastures are used or animal production and nomadic system enable animal to be grazed over a wide area to use the scarce resource available [1]. Production is limited as there is no supplementary feeding unless given on an opportunity basis. Calves or lambs are grazed along with their goats and ewes, and these results in poor growth mates and usually takes two to four years before animals could be marketed or else very low care case weight. The ranged land is over stocked in some areas where demand for food is increasing and output of tradition system is low [2].

The major livestock producing areas, the Sudan-Saherian region of Africa have a long severe dry season of approximately 8 months duration and a short-wet season of about 4 months. Rainfall, the significant climatological parameter, directly affects the productivity of livestock. During the dry season, loss of weight following the dry condition which the ruminant animals, especially cattle, graze on the natural grassland, is a major constraint to efficient livestock production during this period, annual grasses which constitute the main pasture becomes dehydrated, bleached and wilted, as a result of shortage of rainfall. This is an indication of serious losses of nutrient vital to animal growth and production [3].

But Cattle grazing on the proposed designed fodder crops and having enough drinking water have attained live weight gains up to 150 kg per year/animal without nominal supplements and up to 200 kg per year/animal with mineral supplementation of the animal compared to 50 kg/year/herd on the native pasture [4]. Higher stocking rate on stylo pasture [5], could lead to four to six-fold increase in animal production per hectare over that from native pasture [6]. This increase alone may surely offset the cost of integrating any brand of irrigation system into the farm project.

In region of dry Savannah in Africa, large cattle herd are kept under Settled system of alternating farming. This is usually due to population density, the shrinking of available land resources and the emergence of a market. The alternative of land cultivation and grazing is also typical of cattle

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production in Ethiopia, Tanzania and Burundi. In Indonesia, the alternating system is employed for the cultivation and with cattle using plantations at night [1].

Irrigation of Fodder in Ranches. The slow performance of livestock sub-sector in most African countries, especially Nigeria is attributed to nomadic use of outdated pastoral technology and unscientific use of rangeland. Modern ranching is, thus, an improvement over traditional livestock management. The introduction of commercial Cattle ranching in Nigeria is with the aim to boost the supply of milk, meat, butter, and hides not just in the country but to Europe and Anglophone countries of West Africa. Ranching is geared towards transforming the social and economic life of the nomadic. An evaluation of the livestock sector shows that in spite of government policies and incentives, ranching schemes are still insignificant in Nigeria. The restriction of the movement of livestock is seen by the nomadic as a sequential destruction of vegetal resources and an invitation to livestock diseases.

Establishing irrigated ranches to develop fodder for pastoralists require skills and has a lot of advantages in animal businesses. Forage crops offer an excellent solution to filling the forage gap in the months when grass growth slows down [7]. They integrate well with grassland and livestock, aiding in controlling a surplus and offering a high yielding, quality feeds. In addition to these advantages, there is also a benefit for the land in that forage crops are an excellent break crop for grassland renewal. The forage crops can be grazed in situ, meaning there are also benefits to the ground in terms of increased organic matter and return of the grazed nutrients to the soil [7].

There are numerous forage crops available [8], each crop has its own strengths and weaknesses, and these should be compared to one's own situation and requirements. When working out which crop to grow, consideration should be given to the length of time it takes to grow before it can be eaten (utilized) by livestock, season, what class of livestock will be eating the crop, if the plan is to feed in situ in the field or to lift the crop, etc. Irrigation has the potential to improve productivity and provide some risk mitigation in pastoral farming, most especially in the following areas [9]:

– *Feeds availability:* Irrigation enables the production of fodder that can be used as pastoral feeds for feeding stock and maintain stock in their existing conditions [10]. Self-supply of this fodder avoids the purchase of fodder from elsewhere.
– *Weight gain strategies:* Using irrigation to produce good quality pasture and fodder enables pastoralists to turn off cattle at a higher live weight to achieve greater price per kilogram and price per head in the market. The flexibility of being able to feed cattle to a market requirements and at specific times could create an opportunity to maximize profits [11].
– *Improving condition of breeding stock:* Quality pastures also provide the opportunity to improve the condition of the breeding herd. Firstly, heifers weight can be grown to be suitable for mating, thereby accelerating the breeding process. Secondly pastures can be used to improve the condition of cows that are to be mated. Improved cow condition and conception rates will drive overall herd fertility [9, 12].
– *Better control over genetic improvement:* Confining a selection of the breeding herd to irrigated pastures provides an opportunity to command greater control over genetic improvement. Introducing new genetics to animals in improved physical condition and in a controlled environment increases the likelihood of success in introducing improved traits.
– *Capital costs:* The capital costs of developing an irrigation project are significant, particularly in the area of services required for the development of water resources, land clearing and site works. Area/geographic location, resource availability and equipment also considerably influence the viability of the development. The development costs estimate for project of these magnitude are often considered in monetary cost per hectare (Cost/ha), using the following areas: Land and water development, Irrigation equipment, Plant and machinery, Livestock yards and grazing management [9].
– *Land and water resource development:* Development of the water source infrastructure is usually the most expensive component of an irrigation development. These costs include site selection, consultants, production and monitoring bores, pipelines, clearing, fencing, roads and site accommodation. Land development costs can be minimized by good site selection and ensuring suitable soils are close to the water resource. The nature of the water resource and how it is developed will impact on capital development and long-term operating costs [9, 13].
– *Irrigation equipment:* Irrigation water resources are most suitable determining factor for the kind of Irrigation equipment to be used. Sprinkler irrigation systems is one of the best and is suitable for better management of water resources and grazing ranges [10], as water has to be pumped to the irrigation site. Centre pivot irrigators are also recommended because it can travel over undulating terrain and don't require expensive soil levelling that flood irrigation would require. On sandy loam to clay loam soils, centre pivot irrigation is an efficient means of irrigating field crops and pasture [9].
– *Plant and machinery:* A suite of cropping and haymaking machinery would be selected and utilized across the farm hectare (ha) development (per ha harvested fodder crops + ha stand and graze). This would include a tractor, cultivator, harrow, seeder, fertilizer spreader, mower, boom spray, hay rake, baler, bale wrapper, telehandler and shed [14]. All equipment would need to be in good condition as service support may not always be readily available when needed.
– *Livestock management:* Livestock handling yards, feeding facility, cell grazing fencing for the stand and graze pivot areas and perimeter fencing is required [4].
– *Opportunity and Variable costs:* Pastoralists considering irrigated fodder production should consider the opportunity costs involved. These include the use of the water for extending water points and associated fencing for better pasture utilization, and growing other crops. Alternative strategies could also be considered to preserve breeding herds and genetic improvement/agistment.

The variable cost is considered under operating fodder production irrigation area per hectare per annum, fodder annual production and weight gain in young cattle at a feed conversion ratio of 8:1 [9]. Variable cost components are calculated on the basis of a pressurized water supply, cost of solar/diesel generator energy to drive the irrigation equipment and power the machinery shed, and accommodation camp. If irrigation water has to be pumped, using diesel generators, the total cost (diesel, depreciation and maintenance) increases with utilization [15]. The variable cost of feeding cattle in the stand and graze areas, confined feeding area, capital components of the development, are financed and cost on an annualized basis. The total costs of running the irrigated fodder and cattle feeding farm is estimated per annum for the number of hectares' operation as = annualized capital cost + variable costs of fodder production + variable cost of livestock feeding.

Thus, *the aim of research* is to assess and outline the design processes and procedures involved in planning and subsequent construction of a durable ranch farm with irrigation systems. To do this, it is necessary:

– to analyze suitable land area, water sources, irrigation systems, energy requirement and livestock management;

– to outline how to compute for the irrigation systems efficiencies and regulations for drainages and grow improved fodder crop for ranch cattle.

2. Materials and Methods

2.1. Design of ranch irrigation field. Selection of any area is based on soil fertility, availability of a viable water source – its quality, quantity and cost effectiveness. Generally, the following factors are critically investigated before deciding on the method of irrigation to be adopted.

Physical conditions: Topography of the terrain, Soil characteristics, Size of the field, Crop/forage feeds to be grown, Agro-climatology of the area.

Economic and social condition: Cost and availability of equipment and power sources, cost of labour, the knowledge and skills of the farmers.

2.1.1. Soil physic-chemical characteristics. The surface soils of the project area have to be subjected to laboratory analysis to determine the mechanical, physical and chemical properties. Parametric requirement in each test are as follows:

– *Mechanical analysis:* The soil parameters determine under mechanical analysis are Top soil structure, Soil depth, soil Permeability, Soil type and water holding capacity.

– *Physico-Chemical Parametres:* The parameters determine for soil physical properties are; soil texture and soil Organic content, organic matter, while the chemical properties of the soils determined includes soil pH, Nitrogen, Phosphorus, Potassium, Sodium, Magnesium, Calcium, Exchangeable base, cation exchange capacity, exchangeable acidity and base saturation.

2.1.2. Water source and irrigation water quality. Water source for irrigation could be surface (ponds, river, lake, dam) or groundwater (well, borehole, etc.). The choice of water source can be determined by availability, suitability, cost or proximity. Water is tested for different physico-chemical parameters [16]. Selection of parameters to be tested depends solely on the purpose of the water use and extent of its needed quality and purity [17]. For irrigation purposes, most of the parameters that are paramount in irrigation water quality are shown in Table 1 [18, 19].

Table 1

Parameters used in the evaluation of agricultural water quality

Parameters	Unit	Symbol
Physical		
Odour	mg/l	Pt-co
Color	–	–
Temperature	–	°C
Total dissolved solids	mg/l	TDS
Turbidity	ntu	mg/l
Chemical		
Acidity/Basicity	–	pH
Hardness	mg/l	$CaCO^{3-}$
Calcium	mg/l	Ca^{++}
Magnesium	mg/l	Mg^{++}
Sodium	mg/l	Na^{+}
Carbonates	mg/l	CO_3^-
Bicarbonates	mg/l	HCO_3^-
Chloride	mg/l	Cl^-
Sulphates	mg/l	SO_4^-
Sodium absorption ratio	mg/l	SAR
Boron	mg/l	B
Trace metals	mg/l	–
Heavy metals	mg/l	–
Nitrate nitrogen	mg/l	NO_3^-N
Phosphate phosphorous	mg/l	PO_4^-P
Electric conductivity	μS/cm	EC

Different crops vary in their tolerance to salinity and therefore have different thresholds and yield reduction rates. The most common parameters used for determining the irrigation water quality, in relation with its salinity, are Electric conductivity (*EC*) and Total dissolved solids (*TDS*) [20]. Salts of calcium, magnesium, sodium, potassium present in any irrigation water falls collectively under *TDS* [21], Table 2. Natural body and reservoir waters becomes saline if high salt content is present [22], Table 3.

Table 2

Salinity hazard classification based on *EC*, *TDS* and HCO_3

Water quality variables	Class value	Water class	Salinity significance/Interpretation
EC (μs/cm)	<250	Excellent	Low saline water for irrigation use
	250–750	Good	Moderate saline water
	750–2250	Doubtful	High saline water for irrigation use
	>2250	Unsuitable	Very saline water for irrigation use
TDS (mg/l)	<450	Excellent	No problem for all crops to grow
	450–750	Good	Moderately saline water
	750–2000	Permissible	High saline water
	>2000	Unsuitable	Very high saline water
HCO_3 (mg/l)	0.05<75	Excellent	Soft – low saline
	75–150	Good	Moderately hard – moderate saline
	150–300	Doubtful	Hard – high saline
	>300	Unsuitable	Very hard – very high saline

Table 3

Salts normally found in irrigation waters and approximate proportions

Chemical Name	Chemical symbol	Approximate proportion of total salt content
Sodium chloride	$NaCl$	Moderate to large
Sodium sulphate	Na_2SO_4	Moderate to large
Calcium chloride	$CaCl_2$	Moderate
Calcium sulphate (gypsum)	$CaSO_4 \cdot 2H_2O$	Moderate to small
Magnesium chloride	$MgCl_2$	Moderate
Magnesium sulphate	$MgSO_4$	Moderate to small
Potassium chloride	KCl	Small
Potassium sulphate	K_2SO_4	Small
Sodium bicarbonate	$NaHCO_3$	Small
Calcium carbonate	$CaCO_3$	Very Small
Sodium carbonate	Na_2CO_3	Trace to none
Borates	BO_3^-	Trace to none
Nitrates	NO_3^-	Small to none

2.1.3. Design of irrigation systems. The design of the farm area includes laying out of irrigation systems which are; combination of pumping unit with main pipe lines, to the lateral distributors. If the topographical area of the source of water is much higher than the irrigated area, then water flow into the field channels can be by gravity [23]. For example, an earlier topographical survey conducted on field for this research was prepared with 0.5 m contour interval. From this, the canal and drainage system were designed as follows:

– *Pumping plant:* A pumping plant unit with required capacity is installed at the water source to pump the water through the main pipe line laid to the field within a distance 500 m [24].
– *Stilling basin/Levee:* This is to be constructed as per layout plan to contain or dissipate the pressure of water coming from the pumping plant through the main pipe line from which water flows by gravity into the distributary canals. Number of canals to be constructed at each distributary canal transition points depends on farm size.
– *Distributary canal:* There will be two main distributary canals running parallel to the length of the field which divides the farm into a discharge capacity in liters/sec.
– *Field channels:* These are the farm layout, there were 5 field channel to serve five blocks of farm lands. The blocks were designed with uniform capacity, and separate water flow safety.
– *Turn outs, checks and drop structures:* Turn outs are designed based on field channels on each sector, and appropriate number of checks. A total number of drop structures will depend on the steepness of the field, so as to reduce the velocities of the water from one point to another due to field topographic steepness for effective irrigation.
– *Drainage:* Field drains, collectors drain and main drain should be provided for efficient evacuation of excess irrigation water from the irrigation fields. Field channels for drainage should be provided in all irrigation areas under control/day.

2.2. Irrigation water schedule. Irrigation water schedule can depend on the type of forage crop grown. For instance, schedule could be 2 times a week, with 3 days interval, once a day from week 1 to 5, 3 times a week, with 2 days interval, once a day from week 6 to 10, and 2 times a week at week 11 and harvested at week 12, etc.

Various studies have shown that one of the promising irrigation strategies might be deficit irrigation [25], whereby less water than required is applied during the growing period causing crop stress and yield depression. High yield can be obtained by supplying the required amount of irrigation water during sensitive stages, and restricting water stress to tolerant growth stages [26]. Therefore, the irrigation water schedule should be determined by the evapotranspiration of the crop and moisture content of the field soil.

2.2.1. Determination of water consumptive use of the irrigated crops. Consumptive use of evaporation (ET) is the sum of two terms; transpiration, which is water entering plant from the roots and used to build plant tissue and then passed through the stomata of leaves of the plant into the atmosphere. Evaporations; is the amount of water evaporating from adjacent soils, water surfaces or from the surfaces of leaves. Water deposited by dew, rainfall, or irrigation and subsequently evaporates without entering the plant system constitutes parts of consumptive use. Evapotranspiration test is usually conducted on the selected field to determine the evapotranspiration rate (ETo) [27].

2.2.2. Irrigation water requirement. *Net Irrigation requirement (NIR):* This is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity. The net depth of irrigation can be determined from readily available moisture (*RAW*) [28]:

$$RAW = MAD \cdot AW, \tag{1}$$

where *RAW* – readily available water (mm); *MAD* – maximum allowable deficiency; *AW* – available water:

$$RAW = \frac{MAD \cdot Drx \cdot (FC - PWP) \cdot P}{100}, \tag{2}$$

where *Drx* – effective rooting depth of the irrigated crop; *FC* – average field capacity (%); *PWP* – permanent wilting point (%).

Gross Irrigation Requirement GIR: The gross irrigation requirement is the total amount of water applied throughout irrigation:

$$GIR = \frac{RAW}{FE}, \tag{3}$$

where *GIR* – gross irrigation requirement; *RAW* – readily available water; *NIR* – net irrigation requirement, and *FE* – field efficiency of the system.

Irrigation interval/frequency: This is number of days between irrigations during periods without rainfall. The design irrigation frequency = Net depth of irrigation/Transpiration rate of crop:

$$T = ET \cdot \frac{Ps}{85}, \tag{4}$$

where *T* – average transpiration rate of the crop (mm/day); *Ps* – area shaded by the crop as a percentage of the total area (%); *ET* – conventionally accepted consumptive use rate of the crop (mm/day).

Irrigation period (Ip): Irrigation period is the number of days that can be allowed for applying irrigation to a given designed area during the peak of consumptive use period of the crop irrigated [28]:

$$Ip = \frac{(Mb - MI) \cdot FC \cdot BD}{100 \cdot Cu}, \quad (5)$$

where Ip – irrigation period (days); Cu – consumptive use (mm/day); Mb – moisture content at the start of irrigation (%); MI – moisture content in the root zone at the lower limit of moisture depletion (%); FC – field capacity; BD – bulk density [28].

3. Results and Discussion

3.1. Results. Some practical studies and analysis pertinent to this research work were done from a proposed 20 ha scheme land site in Makurdi. Results of the soil mechanical properties were determined and shown in Table 4. The soil physical and chemical properties analyzed are as shown in Table 5. Source of water was from a stream. It was analyzed as irrigation water and compared with irrigation water standards for salinity and sodium salts as shown in Table 6 [19, 29].

The annual evapotranspiration/consumptive use of the study area is 1945 mm/year [30], which equals 162.08 mm/month. This breaks down to monthly consumptive use of 5.40 mm/ha/day.

Therefore, irrigation efficiency $IE = 60$ %.

Hence, field diversion requirement $FDR = 5.40/0.6 = 9.00$ mm/day.

Allowing 20 % peaking factor:

– Total field diversion requirement $TFDR = 9 + (0.2 \cdot 9) = 10.8$ mm/day/ha.

– The equivalent volume $EV = 10.8/1000 \cdot m \cdot 100^2 = 108$ m^3.

– Hence for irrigation interval of 4 days.

– The gross field requirement $GIR = 10.8 \cdot 4$ days $= 43.2$ mm/day/ha.

Since the water holding capacity (WHC) of soil is 143 mm/m and the depth of application is 75.6 mm; this is <143 mm, therefore, water logging, problem is free from the field. For irrigation duration/day:

$$ID/day = \frac{GIR}{infiltration} = \frac{43.2 \text{ mm}}{14.2 \text{ mm/hr}} \approx 3 \text{ hrs.}$$

The equivalent flow rate EFR is computed as:

$$EFR = \frac{(108 \cdot 1000)\text{liter}}{(3 \cdot 60 \cdot 60)\text{sec}} \approx 10 \text{ lit/sec/ha.}$$

Table 4

Mechanical analysis of soils

S/No.	Soil parameter	Unit
1	Top soil structure	0.3 mm diameter
2	Permeability	14.2 mm/hr
3	Soil depth	1 m
4	Soil type	Medium textured soil (Sandy clay silt)
–	Water holding capacity	143 mm/m

Table 5

Mean physic-chemical parameters of the site soils

Sample	pH	% Sand	% Clay	% Silt	*O.C* %	*O.M* %	*N* %	*P* (mg/l)	Units (Cmol/kg)							% *BS*
									K	Na	Mg	Ca	*EB*	*EA*	*CEC*	
Site soil	5.74	69.9	15.16	14.94	1.10	1.65	0.096	4.70	0.26	0.24	1.73	2.93	6.16	1.07	7.23	85.12

Notes: *O.C* – organic content (%); *O.M* – organic matter (%); *EB* – exchangeable base (Cmol/kg); *EA* – exchangeable acidity (Cmol/kg); *CEC* – cation exchange capacity (Cmol/kg); *BS* – base saturation (%)

Table 6

Salinity hazard and sodium salts from the stream as water source compared with standards recommended irrigation water values

Water quality Std.	Water class	Class value	Water source values
EC (μs/cm)	Good	250–750	–
	Doubtful	750–2250	980
	Unsuitable	>2250	–
TDS (mg/l)	Excellent Good	0<450 450–750	65
	Permissible	750–2000	–
	Unsuitable	>2000	–
HCO_3 (mg/l)	Excellent	0.05<75	–
	Good	75–150	78
	Doubtful	150–300	–
	Unsuitable	>300	–
SSP %	Good Unsuitable	<50 >50	25
SAR	Excellent Good Doubtful Unsuitable	10 18 18–26 >26	8

Hence the full supply discharge of a canal for a given area is: flow rate×irrigated area.

For safety and efficiency, all field channels will be designed up to 2.8 hectares/day [31–33], therefore:

– Equivalent flow rate as computed $v_{ef}=10$ lit/sec.
– Discharge capacity for the $F.Cs=10\cdot 2.8$ ha ≈ 28 lit/sec.
– For example, discharge capacity $D.C=10\cdot 20$ ha= =200 lit/sec.

3.2. Design computations for the irrigation water conveyance

3.2.1. Distributor canal for water flow. For the dimensions and parameters for the distributor canal, sectional formula for non-erodible uniform flow is used [34, 35]:

Depth of flow, $AR^{2/3}=Qn/S^{1/2}$.

Type of soil material of the site (Sandy clay silt):

Mannings's coefficient $MC=0.02$.

Bed slope $S=0.15$ %=0.0015.

Computed $D.C$ capacity $Q=200$ lit/sec=0.2 m^3/sec.

$$AR^{2/3}=\frac{0.2\cdot 0.02}{0.0015^{1/2}}=0.103 \text{ designed.}$$

Assuming bed width of the canal $b=0.6$ m.

Depth of flow $y=0.3$ m.

Side slope $S.S=1:1.5$, hence $Z=1.5$.

Area $A=by+Zy^2$.

Wetted perimeter $p=b+2y\sqrt{Z^2+1}$.

Hydraulic radius $R=A/P$.

Therefore,

$$AR^{2/3}=\frac{\left[(b+zy)y\right]^{5/3}}{[b+2y(Z^2+1)]^{2/3}}.$$

Substituting the values of b and y:

$$AR^{2/3}=\frac{\left[(0.6+(1.5\cdot 0.3))0.3\right]^{5/3}}{[0.6+(2\cdot 0.3(1.5^2+1))]^{2/3}}=\frac{0.145831359}{1.414142115}=0.103.$$

$AR^{2/3}=0.103$, or $AR=0.033$.

Since $AR^{2/3}$ computed is approximately equal to $AR^{2/3}$ designed; it implies that b and y are assumed to be okay for the design, therefore: $b=0.6$ m, $y=0.3$ m; $S.S=1:1.5$; $B.S=0.15$ %. And with the provision of the freeboard the total depth (D) of the canal is: $D=0.3+(20\ \%\text{ of }0.3)=0.36$ m.

The Top is $T=2e+b$, where $e=ZD=0.54$.

Hence, $T=2\cdot(0.540+0.6)=1.68$ m (top of the canal).

3.2.2. Design of field drains. The rational formula [36, 37] is used for the design of field drains as follows:

$Q=C\cdot I\cdot A$,

where Q – peak run-off of the area under consideration in m^3/sec; C – runoff coefficient – $C=0.40$; I – rainfall intensity in m/hr – $I=102$ mm/hr; A – area to be drained in km^2.

Therefore,

$$Q=0.40\cdot 102\cdot\frac{2.75\cdot 10000}{1000000}=1.122 \text{ m}^3/\text{sec}.$$

Using Mannings equation, the drain section factor could be found as:

$AR^{2/3}=Qn/S^{1/2}$,

where $S=0.1$ %; $AR^{2/3}=1.122\cdot 0.02/0.001^{1/2}=0.709$.

By trial and error the following values for b and y were computed $b=0.7$ m, $y=0.66$; $S.S=1:1:5$.

Substituting in the equation:

$$AR^{2/3}=\frac{\left[(b+Zy)y\right]^{5/3}}{[b+2y(Z^2+1)]^{2/3}}=$$

$$=\frac{\left[(0.7+1.5\cdot 0.66)\cdot 0.66\right]^{5/3}}{[0.7+(2\cdot 0.66(1.5^2+1))]^{2/3}}=0.567\approx 0.57.$$

3.2.3. Design of pump size. Selection of the pump size [24], for an irrigation project depends on the required discharge per day. Hence the expected discharge per day [38] is determined by:

$$q=\frac{Ad}{Ct},$$

where q – expected discharge from the pump/day in m^3/hr; A – area to be irrigated per day by pumping (20 ha) at 5 days interval which is $(20\cdot 10000)/5=40000$ m^3; d – depth of application in cm (10 cm); constant $C=100$; T – time of application in hours $T=5$ hrs.

Therefore,

$$q=\frac{40000\cdot 10}{100\cdot 5}=800 \text{ m}^3/\text{hr}.$$

Water horse power is computed using the formula [39, 40]:

$$WHP=\frac{Q\cdot H\cdot SG}{3960},$$

where WHP – water horse power – the theoretical power required to lift a given quantity of water each second to a specified height; Q – discharge in m^3/hr; H – total dynamic head in meters (suction+delivery+frictional loss), here, suction head is 10 m, delivery head $H=5$ m; SG – specific gravity of water $SG=1$.

Friction loss:

$H_f=0.33\cdot F\cdot L\cdot Q^2/D^5$,

where F – frictional coefficient of the pipe material (for asbestos pipe $F=0.00874$); L – length of the pipe ($L=9$ m); Q – discharge in m^3/s $Q=800/3600=0.222$ m^3/s; D – diameter of the pipe (0.3).

Hence, H_f=0.33·0.00874·9·0.222^2/0.3^5=0.527.

H=10+5+0.527≈15.53 m.

Therefore,

$$WHP=\frac{0.222\cdot 15.53}{3960}=8.706\cdot 10^{-4}\,\text{hp}.$$

Break Horse power:

$$BHP=\frac{WHP}{Efficiency\ of\ the\ pump}.$$

Assuming pump efficiency=50 %.

BHP=8.706·10^{-4}/0.5=1.741·10^{-3} hp.

But 1 kilowatt=1.341 hp.

BHP=0.105/1.341=1.298·10^{-3} kW.

3.3. Design of irrigation structures. There are various types of irrigation structures used in irrigation engineering and practice. Structures such as drops stilling basin, diversion structures, flumes chute, division boxes, etc.

3.3.1. Design of a stilling basin. A typical stilling basin design should have the following dimensions [41]:
y – sequent depth of hydraulic jump;
y_2 – conjugate depth of hydraulic jump;
$y_2^1=S\cdot y_2$, where S – safety factor;
y^* – depth of stilling basin;
y_o – depth of uniform flow in the downstream channel;
L – length of stilling basin.
Parameters under consideration:

Discharge q=0.222 m^3/s.

Velocity:

$V=q/A$,

where $A=\pi d_2/4$, and d=0.3 m; V=0.222·4/3.142·0.3^2= =3.140 m/s.

Coefficient of discharge (Cd) for rectangular weir Cd=0.75.
Bed slope=0.3 %, and crest height=0.2 m.
a) *Design head:*
To compute design head, the following formula is used [41]:

$q=Q/b$,

where b – length of crest, which is b=2 m.

Therefore, design head=0.222/2=0.111 m^3/s, but $Q=2/3Cd\sqrt{2g}bHd^{3/2}$. Since $q=Q/b$.

Therefore,

$$0.111=2/3 0.75\sqrt{2\cdot 9.81}\cdot Hd^{3/2};$$

$$0.111=0.5\sqrt{2\cdot 9.81}\cdot 2\cdot Hd^{3/2};$$

$Hd^{3/2}$=0.02505956207;

Hd=0.086.

b) *Loss coefficient on spill way*
Loss coefficient is calculated using the formula [42]:

$Q=1-0.0155S/H$,

where S – height of crest S=0.8 m, H=0.214.
Therefore Q=1–0.0155(0.8/0.214)=0.942
c) *Depth of uniform flow* – y_o.
Using manning's equation:

$V=1/nr^{2/3}S^{1/2}$,

where n=0.045, r is assumed y (for wider channels), hence:

$q=Vy_o=1/ny_o{}^{2/3}S^{1/2}y_o$,

$$0.111=1/0.045\left(y_o{}^{2/3}y_o/1\right)\cdot\sqrt{0.8},$$

$0.111=19.876y_o{}^{5/3}$,

$y_o=(0.219)^{3/5}$=0.044.

d – segment depth y_1 (of hydraulic jump) this is given by the formula [43]:

$E=y_1+q^2/2gy_1{}^2Q^2$,

where E – crest height + design head=0.2+0.214=0.414 m.
Hence, 0.414=y_1+0.0479/$y_1{}^2$·17.41.
By trial and error y_1=0.41 m.
Conjugate depth (y_2) this is given by:

$y_2=y/2(-1+\sqrt{1+8fr_1^2})$,

where $fr_1^2=V_1^2/gy_1=q^2/gy_1^3=\frac{0.047892}{9.81x0.413}=0.0034.$

Therefore, $y_2=0.41/2\left(-1+\sqrt{1+(8\cdot 0.0034)}\right)=0.003$ m.

Since y_2 (0.003 m)<y_o (0.36 m), the stilling basin is not required for the transition point. The condition stipulates that stilling basin or energy dissipater is required when $y_2>y_0$ [43].

3.3.2. Drop structures. Drop structures convey water from one elevation to another without causing erosion. A drop structure is a low wall constructed with a channel across its entire width. Different shapes, heights and construction materials are used depending on their location and purpose [44].

Drops structures are structures used in places where natural slopes, down-ward along which water flow are high that could cause excessive water velocities and erosion in banks and bed of channels, if not provided.

Drop structures can be constructed using wood and concrete or masonry. Vertical drops generally incorporate stilling begin and form of sill or baffle or both, combined with Side wall arrangement to dissipate the jet. These structural arrangements create a reverse rolling flow at ground level, hence reducing scouring of the channel bed to prevent erosion; rip-rap is placed at the downstream [45].

The dimensions of the stilling pool or energy dissipater depend upon the height of the drop and the discharge over the crest. Hydraulic jump may be formed downstream and from experimental results, the flow geometry of a vertical drop structure is described by a function of the 'drop numbers' [46], defined as:

$$D=q^2/gh^3,$$

where D – discharge per unit width of the crest over fall in m^3/second; q – discharge in m^3/hr; g – acceleration due to gravity; h – height of the drop in meters.

Drop length is found by using the formula [46]:

$$Ld/h=4.3D^{0.27},$$

where Ld – length of drop in meters; h – height of drop in meters; d – number of drops.

3.3.3. Turn outs. Turn outs are structures constructed at junctions of the main distributor and field channels as main and appropriate division of irrigation water. The structures are made of wood, concrete and steel [47].

3.3.4. Estimation of required materials. Major estimates of materials required for the construction of structures are categorized as follows [48]:

– *Distributor Canal Earth Material (Filling and compaction):*

$$A=1/2(1.68+0.6)\cdot 0.36=0.4104\ \text{m}^2.$$

Volume of earth material $V_{em}=(0.4104\cdot 550)\cdot 2=451.4\ \text{m}^3$.

– *Field channels earth material (Filling and compaction):*

$$A=1/2(0.66+0.3)\cdot 0.576\ \text{m}^2.$$

Volume of earth materials $V_{em}=(0.0576\cdot 500)\cdot 5\cdot 2=288\ \text{m}^3$.
Total volume of filling and compaction earth material= ={288+451.4}+20 % for consolidation x compaction=887.3 m^3.

– *Drainage Excavations (earth material):*

Area $A=1/2(3.076+0.7)\cdot 0.792=1.773\ \text{m}^2$.

Volume of earth $V_e=(1773\cdot 500)\cdot 5\cdot 2=8862.5\ \text{m}^3$.

– *Metal gates for turn – outs.*
Size dimensions, 0.6×0.36 m (× required number).

3.4. Discussion

3.4.1. Soil and irrigation water quality. Some of the practical studies and analysis done from the proposed 20 ha scheme land site in Makurdi, were done to guide and illustrate the necessary field research works that must be carried out on any proposed ranch farm in preparation for the planning of the fodder crops and design of the irrigation systems in any selected site.

Thus, results of the soil mechanical properties as shown in Table 4 was done to determine the soil constituents – predominant soil constituents and characteristics of the site soil, Particle size distribution, structure, type and water holding capacity of the soil, which is important in irrigation planning.

The soil physical and chemical properties analyzed indicates the soil elemental and nutrient contents. Other soil characteristics of organic content (%), organic matter (%), exchangeable base, exchangeable acidity, cation exchange capacity and base saturation (%), helps to determine the field capacity (*FC*) of the soil, permanent wilting point (*PWP*), density, available moisture content (percentage %), moisture content (%), etc. (Table 5).

Source of water from a stream was analyzed as irrigation water to illustrate how irrigation water standards can determined the level of salinity and sodium salts in the intended irrigation water, Table 6. The test for salinity hazard and sodium salts, measured inform of *EC, TDS, HCO, SSP %* and *SAR*. The analyzed water from the stream was found to be suitable for irrigation, except *EC* whose concentration (780 µs/cm) was above the minimum standard of 750 µs/cm, falls under a water class of «Doubt full» (Table 6), therefore, concentration of *EC* parameter has to be treated, depending on the water use.

The characteristics that affect irrigation water systems were equally determined in the areas of Evapo-transpiration (consumptive use), Net Irrigation Requirement (*NIR*), Gross Irrigation Requirement (*GIR*), Irrigation interval/frequency, Irrigation interval (*It*), Irrigation period (*Ip*). The determination outlines the processes involved in planning for the irrigation water.

3.4.2. Designing irrigation systems and structures. Procedure of how to compute for the field irrigation system was calculated for Distributor Canal of water flow (Depth of flow, Bed slope, Hydraulic radius, freeboard the total depth, top of the canal); design of field drains involving peak run-off of the area under consideration, rainfall intensity, drain section factor.

Design of pump size: Computation was done on how to select pump size for an irrigation project depending on the required discharge and pump efficiency per day.

Design of Irrigation Structures: Design calculations were done for drops stilling basin, diversion structures, flumes chute, and division boxes, using the parameters for design head, Loss coefficient on spill way, segment depth of hydraulic jump and Conjugate depth. Others are Drop structures and Turn outs for discharge per unit width of the crest over fall, depending on location and purpose, and main distributors and field channels.

Thus, all the computational procedures discussed above are tentative and the numerical values obtained from the calculations are for research guidance only. Therefore, for practical application, detail study that is site specific must be carried out, with further research on the design parameters.

4. Conclusion

In this study, it is able to obtain and outlined all the designed parameters for the design of an improved irrigation scheme for Fodder Crop Production for ranch cattle. Soil physic-chemical characteristics of the selected land area were analyzed to be loamy, water source and irrigation water quality was suitable. irrigation systems designed for consumptive use, Net Irrigation Requirement (*NIR*), Gross Irrigation Requirement (*GIR*), Irrigation interval/frequency, Irrigation interval (*It*), Irrigation period (*Ip*), showed numerical values to be all suitable, because the water holding capacity of the soil is 143 mm/m and the depth of application was computed to be 75.6 mm; which is less than 143 mm, therefore, water logging, problem is free from the field.

The design for the distributor canals and structures were for medium size of 20 ha, the designed calculated values all falls under the recommended standard design. It is recommended that further details be made on all the design parameters because project of this magnitude depends on site data.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Amole, T., Augustine, A., Balehegn, M., Adesogoan, A. T. (2021). Livestock feed resources in the West African Sahel. *Agronomy Journal, 114 (1),* 26–45. doi: https://doi.org/10.1002/agj2.20955
2. Zougmoré, R., Partey, S., Ouédraogo, M., Omitoyin, B., Thomas, T., Ayantunde, A., Ericksen, P., Said, M., Jalloh, A. (2016). Toward climate-smart agriculture in West Africa: a review of climate change impacts, adaptation strategies and policy developments for the livestock, fishery and crop production sectors. *Agriculture and Food Security, 5 (1).* doi: https://doi.org/10.1186/s40066-016-0075-3
3. Beede, D. K., Collier, R. J. (1986). Potential Nutritional Strategies for Intensively Managed Cattle during Thermal Stress. *Journal of Animal Science, 62 (2),* 543–554. doi: https://doi.org/10.2527/jas1986.622543x
4. Zhang, Z., Whish, J. P. M., Bell, L. W., Nan, Z. (2017). Forage production, quality and water-use-efficiency of four warm-season annual crops at three sowing times in the Loess Plateau region of China. *European Journal of Agronomy, 84,* 84–94. doi: https://doi.org/10.1016/j.eja.2016.12.008
5. Walker, L. K., Peck, G. A., Mace, G., Buck, S. (2022). *Stylos in Queensland: an identification and suitability guide for graziers and advisers.* Brisbane: Queensland Government, 27.
6. Partridge, I., Middleton, C., Shaw, K. (1996). *Stylos for Better Beef, Queensland Department of Primary Industries.* Brisbane.
7. Kirsten, W., Gavin, E. (2020). *Forage Crops for Livestock.SRDP. Farm Advisory Service.* Available at: https://www.fas.scot/downloads/technical-note-tn733
8. Kirsten, W., Gavin, E. (2022). RB209. *Grass and Forage Crops.* Available at: https://ahdb.org.uk/knowledge-library/rb209-section-3-grass-and-forage-crops
9. *Developing and operating an irrigated fodder enterprise in the Pilbara-financial considerations* (2017). Western Australian Agriculture Authority.
10. Enciso, J., Porter, D., Fipps, G., Colaizzi, P. (2020). *Irrigation of Forage Crops. B-6150, 5/04.* Available at: https://www.researchgate.net/publication/26904662_Irrigation_of_Forage_Crops
11. Ali, A., Mustafa, M. I., Bilal, M. Q., Muhammad, G., Lateef, M., Ullah, S. (2015). Effect of watering frequency on feed intake, milk production and composition in Sahiwal cattle during summer. *Journal of Animal and Plant Science, 25 (1),* 19–22.
12. Hailesilassie, H. (2016). The effect of improved fodder production on livestock productivity in Endamehoni District, southern Tigray Ethiopia. *Land Resource Management and Environmental protection.* Available at: https://hdl.handle.net/10568/81207
13. Attia, S. S., Hani, A. G., Meg, M. A., Kalil, S. E., Arafa, Y. E. (2019). Performance analysis of pressurized irrigation systems using simulation model technique. *Plant Archives, 19 (1),* 721–731.
14. Buckmaster, D. R. (2019). Equipment Matching For Silage Harvest. *ASABE, 25 (1),* 31–36.
15. Jekayinfa, S., Ogunshina, M., Oke, A., Ojo, O. (2018). Energy requirements for irrigation water supply of selected schemes in Nigeria. *Misr Journal of Agricultural Engineering, 35 (2),* 571–586. doi: https://doi.org/10.21608/mjae.2018.95798
16. Tiri, A., Belkhiri, L., Asma, M., Mouni, L. (2020). Suitability and Assessment of Surface Water for Irrigation Purpose. *Water Chemistry.* doi: https://doi.org/10.5772/intechopen.86651
17. Nair, A. P., Ganga, S., Kumbhar, R. R. et al. (2022). Assessment of water quality of different water bodiesin and around Mumba. *International Journal for Research Trends and Innovation, 7 (5),* 387–393.
18. Kandiah, A. (1990). Water quality management for sustainable agricultural development. *Natural Resources Forum, 14 (1),* 22–32. doi: https://doi.org/10.1111/j.1477-8947.1990.tb00364.x
19. Singh, K. Kr., Tewari, G., Kumar, S. (2020). Evaluation of Groundwater Quality for Suitability of Irrigation Purposes: A Case Study in the Udham Singh Nagar, Uttarakhand. *Journal of Chemistry, 2020,* 1–15. doi: https://doi.org/10.1155/2020/6924026
20. Corwin, D. L., Yemoto, K. (2017). Salinity: Electrical Conductivity and Total Dissolved solids. *Methods of Soil Analysis, 2 (1).* Available at: https://www.researchgate.net/publication/320456153_Salinity_Electrical_Conductivity_and_Total_Dissolved_Solids
21. Gidey, A. (2018). Geospatial distribution modeling and determining suitability of groundwater quality for irrigation purpose using geospatial methods and water quality index (WQI) in Northern Ethiopia. *Applied Water Science, 8 (3).* doi: https://doi.org/10.1007/s13201-018-0722-x
22. Guy, F. (2019). *Irrigation Water Quality Standards and Salinity Management Strategies.* Available at: https://twon.tamu.edu/wp-content/uploads/sites/3/2021/06/irrigation-water-quality-standards-and-salinity-management-strategies-1.pdf
23. Abdurehman, A. (2018). *Irrigation system Layout and Canal Design.* Ethiopian Water Technology Institute. Available at: https://www.academia.edu/50892899/
24. Muhammad, N. J. (2021). *Designing Consideration of Irrigation System Hydraulics. Sizing & Capacity Calculations of the Motor-Pump Set.* Available at: https://www.fao.org/3/cb3484en/cb3484en.pdf
25. Ali, M. H., Talukder, M. S. U. (2012). Increasing Water Productivity in Crop Production. *American Journal of Potato Research, 80,* 271–279.
26. Al-Kaisi, M. M., Broner, I. (2014). *Crop Water Use and Growth Stages.* Colorado State University. Available at: https://extension.colostate.edu/docs/pubs/crops/04715.pdf
27. Malum, J. F., Egwemi, E. O., Enduna, Y. (2022). Performance Evaluation of Improvise Drip Irrigation System. *European Journal of Advances in Engineering and Technology, 9 (7),* 1–10.
28. Edoga, R. N., Edoga, M. O. (2006). Design of Drip Irrigation for Small Vegetable Gardeners. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 34,* 134–139.
29. Ayers, R. S., Westcott, D. W. (1985). Water Quality for Agriculture. *FAO.* Irrigation and Drainage (Paper 29).
30. Wuese, S. T., Agber, P. I., Kalu, B. A. (2019). Assessment of Consumptive use and Water use Efficiency of Okra (abelmoschus esculentus l. Moench) Using Minilysimeters in Makurdi, Benue State, Nigeria. *Journal of Agriculture and Horticulture Research, 2 (1).* doi: https://doi.org/10.33140/jahr.02.01.05
31. Chp. 6: Irrigation Water Schedule (2007). Handbook for Engineers. *FAO.* Available at: https://www.fao.org/3/a1336e/a1336e06
32. Smith, R., Uddin, M. (2020). Selection of flow rate and irrigation duration for high performance bay irrigation. *Agricultural Water Management, 228,* 105850. doi: https://doi.org/10.1016/j.agwat.2019.105850
33. Brian, B., Sanjay, S. (2019). *Water Measurement For Agricultural Irrigation and Drainage Systems.* Available at: https://edis.ifas.ufl.edu/publication/CH153
34. Haseeb, J. (2017). *Design of Non Erodible Channels.* Available at: https://www.aboutcivil.org/Design-Of-Non-Erodible-Channels.html

ISSN 2664-9969

35. Imad, H. (2021). *Cross section of an Irrigation Canal. Irrigation and Drainage Engineering*. Available at: https://www.uobabylon.edu.iq/eprints/publication_7_25809_838.pdf
36. Field drainage guide Principles, installations and maintenance (2018). *Agriculture and Horticulture Development Board*. Available at: https://ahdb.org.uk/drainage
37. Lester, A., Tinkham, P. E. (2020). *Use of Rational Formula For Hydraulic Analysis Design*. Available at: https://pdhonline.com/courses/h147/h147content.pdf
38. Kashif, M., Tajammal, H. A. (2022). *Irrigation Pumping Systems*. Available at: https://www.zef.de/fileadmin/user_upload/kmehmood_download_Chapter-8.pdf
39. Blair, S. (2013). *Understanding Water Horsepower*. Available at: https://pubs.nmsu.edu/_m/M227/index.html
40. Luke, S. (2023). *How to Calculate and MeasureWater Pump Horse Power*. Available at: https://www.wikihow.com/Calculate-Water-Pump-Horsepower
41. Agha, M. A. (2020). *Stilling basin Design and Construction*. doi: https://doi.org/10.13140/RG.2.2.28552.85768
42. Boes, R. M., Hager, W. H. (2003). Hydraulic Design of Stepped Spillways. *Journal of Hydraulic Engineering, 129 (9),* 671–679. doi: https://doi.org/10.1061/(asce)0733-9429(2003)129:9(671)
43. Peterka, A. J. (1994). Hydraulic Design of Stilling Basins and Energy Dissipators. *Engineering Monograph, No. 25*. Available at: https://www.usbr.gov/tsc/techreferences/hydraulics_lab/pubs/EM/EM25.pdf
44. *Drop Structures. Technical Note No. 5 Erosion and Sediment Control Guidelines* (2022). Department of Land Resources Management. Available at: https://wildlife.lowecol.com.au/wp-content/uploads/sites/25/Drop-Structures.pdf
45. Humphreys, H. W., Gunnar, S., James, H. O. (1970). *Model Test Results of Circular, Square, and Rectangular Forms of Drop-Inlet Entrance to Closed-Conduit Spillways*. Illinois State Water Survey, Urbana, Report of Investigation, 65.
46. Skutch, J. (1997). Minor Irrigation Design Drop – Design Manual Hydraulic. *Analysis and Design of Energy-dissipating Structures*. https://assets.publishing.service.gov.uk/media/57a08db1e5274a31e00019cc/R5830-odtn86.pdf
47. Adrian, L. (2007). *Irrigation Systems Design, Planning and Construction*. CABI.
48. Muhammad, J. M. C., Mohammad, J. K., Abid, S. (2018). *Channel Design and Control Structures*. Available at: https://www.researchgate.net/publication/323110643

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