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Utility Vehicles and Mini Trucks utilization as Mini Tractors for Small and Medium Scale Farming operation

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Abstract: *A utility vehicle is a vehicle that is designed to travel over rough ground.Land Rovers, Jeep, Range rovers and Honda Pilotare brands of utility vehicles in Nigeria. They are high-powered automobiles, first mass-produced for the United States armed forces in 1940. A utility vehicle combines the ruggedness of a truck with the speed and mobility of a light car. Essential features are a powerful engine, two- and four-wheel drive, and deep-treaded tires. A standard utility vehicle can haul a load of half a ton or more and maneuvers well over mud or hilly terrain. Modern utility vehicles available commercially, are often capable of traveling at speeds of 144 km/h (90 mph) or greater. Farming is a rough terrain operation. On farm vehicles should be fitted with deep treaded tires with rim and tire diameter enabling high ground clearance to maneuver studs and bumps which are normal occurrence in farms. Such tires are classed by the American Society of Agricultural and Biological Engineers (ASABE), as agricultural tires. These utility vehicles and mini-trucks are built with high ground clearance and fitted with agricultural tires. Some mini trucks in Nigeria namely: Dyna; Mistubishi and Daihatsu amongst others, possess the required ground clearance and requisite tires to be employed as agricultural vehicles just as utility vehicles. It is a fact that continuous agro mechanization programmes of various administrations in the country since the 1950's have been in the lines of the vicious circle of a). Tractor Importation b). Tractor Spare Parts Problem c). Tractor Maintenance Problem and d). Tractor Abandonment. The first reason is that imported tractors are very specialized vehicles with very few trained mechanics in Nigeria to service them. The second is that the spare parts are not readily available. Chiefly for these reasons tractor utilization in Nigeria shall continue to constitute a problem for farmers in the country until we create farming vehicles from the commonly used utility vehicles and mini-trucks in the country, wherefore the spare parts and skilled mechanics would be readily available. This work contrives a method for the conversion of Utility vehicles and mini-trucks intomini tractors for small and medium scale farming operations in Nigeria. It is a need driven appropriate technology to revolutionize farming in Nigeria in particular and in other developing countries.*

Keywords: *Agriculture, ground clearance, tire, Utility vehicle, Mini-truck, Tractor.*

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I. Introduction

The Nigeria population according to the 2006 census was estimated to be about 140,003,542m. About 75% of this estimated population is directly or indirectly dependent on agriculture for their livelihood. Agriculture which is the artificial cultivation and processing of animals, plants, fungi and other life forms of food, fiber and other by products, therefore, plays a unique role in the nations' economy. Due to an ever increasing demand for food as a result of population growth and a wide variety of nutritional requirements, the existing gap between food and population expansion, cultivable land and labour has significantly increased. (Adofu*et al.*, 2003).

Agricultural mechanization is the application of mechanical technology and increased power to agriculture, largely as a means to enhance the productivity of human labour and often to achieve results well beyond the capacity of human labour. This includes the use of tractors of various types as well as animal-powered and human-powered implements and tools, and internal combustion engines, electric motors, solar power and other methods of energy conversion. Mechanization also includes irrigation systems, food processing and related technologies and equipment. Mechanization is not an "all or nothing" process. Levels and types of improved mechanical technologies need to be appropriate, that is, compatible with local, agronomic, socio-economic, environmental and industrial conditions. (FAO 2008).

Agricultural mechanization implies the use of various power sources and improved farm tools and equipment, with a view to reduce the drudgery of the human beings and draught animals, enhance the cropping intensity, precision and timelines of efficiency of utilization of various crop inputs and reduce the losses at different stages of crop production. The end objective of farm mechanization is to enhance the overall productivity and production with the lowest cost of production. The contribution of agricultural mechanization has been well recognized in enhancing the production together with irrigation, biological and chemical inputs of high yielding seed varieties, fertilizers, pesticides and mechanical energy. (Verma 2008).

On average, agricultural productivity in sub-Saharan Africa is poor. To increase the productivity of agriculture in sub-Saharan Africa, cultivation must be both intensified and extended. Manual cultivation is used commonly by farmers but it is technically inefficient, labour intensive and poor yielding. To increase productivity, there is need for improved appropriate and sustainable technology. The experience in many developing countries including Nigeria is that tractors have not been an appropriate solution. (Daramola 1999).

Farm power has been insubstantial demand in the rural areas of the country, where the bulk of the small-scale farmers who produce the food requirements of the ever growing population reside. These set of farmers use human muscle to cultivate small farms supplying about 90% of energy to produce food crops for consumption in the country thus lowering production. Efforts by the Federal Government of Nigeria to improve this situation led to the massive importation of engine drawn implements like tractor etc. in the 1970s and 1980s as a result of the oil boom. However the use of these implements which is said to increase productivity is quite expensive and hard to access by the rural farmers in a depressed economy like Nigeria where these categories of farmers hardly get enough to feed themselves and their families and take care of other basic needs. (Ja'afar-furo 2010).

Several Nigerian Government Agricultural Programmes such as Operation Feed the Nation (OFN), Green Revolution and Food for All Programme, have been geared towards tractorization which have not yielded expected results, for a number of reasons such as: lack of skilled operators and personnel, lack of suitable implements and spare parts, farm land fragmentation, and increase in the cost of tractors and implements. (Abubakar and Ahmad 2010). Despite the concerted effort to introduce mechanization and improved seeds, the desired goal of realizing sufficiency in the production of food, cash crops and agro-industrial raw materials has not been fully achieved. The operation of imported machinery has been bedeviled by the problems of spare parts, repair facilities, capital, skill manpower (operators and mechanics) and the fact that most machinery applications are incompatible with farmers cropping techniques. Available information showed that 1000 tractors imported in 2003 were without required implements, thus rendering them unusable. Also about 50.5 percent of the estimated 10,000 tractors in the country are in a state of disrepair. (Ukeje 2004). To get it right, Nigeria needs to develop its farm cultivation machinery from the already assimilated technologies within its boundaries.

II. Statement of the Problem

In 2006, the World Food and Agricultural Organization (FAO) classified levels of agricultural mechanization. Farm sizes close to and above 50ha are classified as large farms which are suited to tractor operation. Those of 5ha and above are classified as medium farms most viable for animal traction. Farm lands of not more than 5ha are small sized farms currently undertaken by human labour. Currently 86 percent of farm lands in Nigeria are cultivated by human labour, 6 percent by animal traction and 9 percent by tractor power. (Takeshima and Salau 2010).

In sub-Saharan Africa and especially in Nigeria farm lands are fragmented mostly in the range of less than one hectare to about ten hectares. Only very few farm lands in Nigeria are close to fifty hectares. It is thus clear that apart from cost and maintenance difficulties, land fragmentation is another setback to viable tractor utilization in Nigeria.

In concluding their study on a Survey of Animal and Tractor Farming Techniques in Jigawa and Kano States of Nigeria; Amonye *et al*., 2014 reports that tractor users having enjoyed the benefits thereof would wish to continue its usage. However the conditions they requested for effective operations are impossible. That Government should import more tractors, import more spares and make them as available as other automobile spare parts in the country, and also train more persons in the repair and maintenance of tractors. How many types of tractors, makes and models have we imported and from where? How much money shall the country spend in importing more and from where? What quantity of yield are we expecting at the end of the day? These are questions awaiting answers for utilization of tractor to try to start to work.

The scenario in farm power utilization is pitiable. The tractors which can work are inadequate, expensive, lacking in spare parts and demanding highly skilled manpower to maintain and repair; which skills are not available in the country. Animal traction which is the next alternative is beset by myriad of problems from lack of feeds, healthcare problems, farmer education to poor and inadequate funding of extension services in that regards. There is need for a technology of farm power which unlike the tractor, shall not be expensive and shall have available spare parts and at the same time requiring only the much available technical potentialities of Nigerian craftsmen and technicians to maintain and repair. And similarly unlike animal traction, shall not be beset with healthcare or feeds problems that may lead to low productivity.

This technology- “Utility vehicles and mini trucks utilization as Mini Tractors for Small and Medium Scale Farming Operations”, is contrived to solve this problem by developing a system whereby readily available vehicles in the country which spare parts and skilled technicians abound, shall be converted into tractors for small and medium farm operations.

III. Objectives

The broad objective of this work is to enhance agricultural productivity by developing a methodology for the conversion of utility vehicles and mini-trucks into mini-tractors. The specific objective is to design a tractor employing locally available utility vehicles and mini-trucks for traction.

IV. Materials and Methods

The methodology entailed physical and literature survey of some commonly used utility vehicles and mini trucks in Nigeria. Investigation into the force requirement of the cultivation tool (cultivation being the hardest agricultural operation) to be drawn by the converted tractor and designing the tractor with a novel type of hitch to ensure smooth mechanical on-farm work. The mini tractors are contrived to pull animal-drawn implements and as such the draft requirements and speeds are to be maintained at levels close to the parameters occurring in animal on-farm work.

V. Literature Survey

Common off-road vehicles used in Nigeria include the Land Rover, Range Rover, Honda Pilot, Toyota Land Cruiser etc. Some of their power ratings and other specifications from internet catalogue sites and Wikipedia are given hereunder.

Land Rover: Engines used by the British company Land Rover in its 4×4 vehicles have included 4-cylinder petrol engines, and 4-cylinder and 5-cylinder diesel engines. 6-cylinderengines have been used for Land Rover vehicles built under license. Land Rover has also used various 4-cylinder, V8 engines and V6 engines developed by other companies. Some specifications include: (Wikipedia 2015). Layout: 4-cylinder, in-line Block/head: Cast iron/aluminum alloy. Valves: OHV, belt-driven camshaft, push-rod operated. Capacity: 2,495 cc (152.3 cu in). Bore × stroke: 90.47 mm × 97 mm (3.562 in × 3.819 in). Compression ratio: 19:1. Fuel injection: Bosch VE rotary pump + Bosch two-stage injectors. Power: 111 hp (83 kW) @ 4,250 rpm (Discovery.Plate 1 shows Land Rover frame with drive components.

Land Cruiser: The Toyota F series engine was a series of OHV inline-6-cylinder engines produced by Toyota between 1955 and 1992. They are known for their high amount of torque at low RPM, massive cast-iron blocks and heads and also their high reliability. The engine was first introduced in the Land Cruiser, and in many countries, was the only engines offered in the Land Cruiser until 1993. Although it's commonly badged as the Land Cruiser engine, it was used in a variety of other large truck applications as well, such as in fire trucks and the Toyota FQ15 trucks. It was also used in the Crown-based Japanese police patrol cars FH26 and FS20-FS50. The F engine is a 3.9-liter, 75/93 kW (105/125 hp), carbureted gasoline engine that is capable of 261/289 Nm (189/209 lbft) of torque at 2000 RPM; the difference in power and torque is different depending on the export destination. The original design was started in the early 1950s when Toyota had begun to export their vehicles internationally. (Wikipedia 2015).

Honda Pilot: 250-hp, 3.5-Liter, 24-Valve SOHC i-VTEC® V-6 Engine. Every Pilot is powered by a 250-hp @ 5700 rpm (SAE net), 3.5-liter, aluminum-alloy, 24-valve SOHC i-VTEC® engine featuring the latest version of Honda's advanced Variable Cylinder Management™ (VCM®) system.

Range Rover: The Range Rover is a large luxury four-wheel drive sport utility vehicle (SUV) produced by British car maker Land Rover, a subsidiary of the Indian multinational conglomerate Tata Group, and serves as its flagship model. The model, launched in 1970, is now in its fourth generation. Land Rover has expanded the Range Rover model line to include two entirely different designs: the Range Rover Evoque and the Range Rover Sport that derive core styling, brand identity and breadth of capability from the current Range Rover model. Plate 2 shows a Range Rover frame with drive components. (Wikipedia 2015).

Plate 1: Land Rover Frame showing drive components

Plate 2: Range Rover Frame showing drive components

VI. Tillage and its Implements

Tillage is the agricultural preparation of soil by mechanical agitation of various types, such as digging, stirring, and overturning. Examples of human-powered tilling methods using hand tools include shoveling, picking, mattock work, hoeing, and raking. Tillage is the first and the most important operation in crop production. (Askari and Khalifahamzehghasem 2013). Tillage operations are generally carried out before sowing or planting. Primary tillage is otherwise called ploughing which is opening of compact soil with tools and implements. Tillage is the base operation in agriculture and its energy represents a considerable portion of the energy utilized in crop production. Land preparation is one of the most important operations of agricultural mechanization and the most expensive operation consuming high cost of the power. Farm mechanization has been helpful to achieve a significant improvement in agricultural productivity. Thus, there is strong need for mechanization of agricultural operations. Soil tillage is carried out by many different implements and it is one of the most determinant of operations in agricultural production. (Abualgasim and Dahab 2013).

The mouldboard plough (Plate 3), has always been the basic tillage implement on the farm. Although historic, it is still useful and widely employed for primary tillage. It cuts the soil slice, lifts it over the surface of the mouldboard and inverts it, burying the surface growth and crop residues to leave a clear surface for subsequent cultivation. The animal-drawn mouldboard plough is widely used for primary tillage in the developing counties of Africa. This is due to its low cost and the availability of working animals such as oxen, cows, donkeys, horses and mules. Generally the mouldboard plough works well as a low speed soil inverting implement and improvements in the design can be obtained mainly by reducing draught and wear. It was estimated that the friction component of draught contributes about 30% of the total draught for ploughs working at a speed of 3 km/h. It is reported that draught forces in animal-drawn ploughs vary from 850 N to 2,000 N depending upon the type of the soil and its moisture content. (Loukanov*et al.*, 2005).

Plate 3: Animal Drawn Plough

VII. Drawbar Power and Speed

The Nebraska Tractor Test Laboratory (NTTL) at the University of Nebraska is the official U.S. tractor-testing station for the Organization for Economic Cooperation and Development (OECD). This laboratory is responsible for testing a representative tractor of each model sold in the state of Nebraska. It also tests tractors manufactured in the United States and sold in international markets. The laboratory publishes the results of all tests conducted. (Grisso*et al.*,2009). Table 1 gives percentages of engine power available for drawbar work in different soil conditions as worked out by Nebraska Tractor Test Laboratory.

Table 1: Tractor power available as drawbar power in different soil conditions. (Source: Grisso et al 2009).

Power Application	Traction condition			
	Con-crete	Firm Soil*	Tilled Soil†	Loose Soil‡
	Per-cent	Per-cent	Per-cent	Per-cent
Maximum observed PTO horse-power (Nebraska Tractor Test Data expressed as a percent)	100.0	100.0	100.0	100.0
Less losses in transmitting power to wheels, and rolling resist-ance and slippage losses on concrete	−15.0	−15.0	−15.0	−15.0
Maximum potential horsepower available at tractor drawbar	85.0	85.0	85.0	85.0
Deductions for overload reserve, emergency, and safety	−17.0	−17.0	−17.0	−17.0
Potential usable drawbar horse-power	68.0	68.0	68.0	68.0
Power losses due to rolling re-sistance and tire slippage, as affected by the traction sur-face	− 0.0	− 5.5	−13.0	−20.5
Drawbar horsepower actually available to the implement	68.0	62.5	55.0	47.5

Power is defined as the rate of doing work or work done per unit time. In S. I. units, the unit of power is watt (briefly written as W) which is equal to 1Joule per second (J/s) or 1newton metre per second (1N-m/s). Thus the power developed by a force of F (in newton) moving with a velocity v m/s is equal to:

P = F x v. watts. ---------------------- (1)

Similarly if T is the torque transmitted in N-m or J and w is the angular speed in rad/s; the power

P = Tw = T x 2πN/60 watts -------------- (2)

Since w = 2πN/60 -------------------------- (3)

Where N= Revolutions per minute (Khurmi and Gupta 2002).

$$v = wr \text{ ------------------------------ } (4)$$

Where r is the radius of the shaft.

The implication of the power equations 1 and 2 is that for a given value of power, the desired design values of force and velocity or torque and angular velocity can be extracted by varying the counterpart component accordingly. Hence large force or torque can be extracted at low velocities while increased speed can be achieved at the expense of force and torque. For a vehicle used for transport, the desired function is speed in so offer as enough force is allowed for carrying the vehicle mass and that of goods and passengers. A farm vehicle or tractor however requires great force to be able to pull the implements easily across the soil. Hence there is need for reduction in speed below the lowest speed when the utility vehicle is used for transport.

VIII. Transmission

The transmission is such that when the engine crankshaft is rotated, the speed (Rpm) at the flywheel is transmitted to the gearbox (manual transmission shown in figure 1). The speed at entry through the clutch is the same as engine speed which outputted at any of the gear ratios (Gear 1 to Gear 4 in the forward and the Reverse Gear) through the tail. The reduced speed at the tail or output of the gearbox is then transmitted to the tires through the axle (Differential) at a constant axle gear ratio. By so doing the vehicle moves in the direction of the arrow.

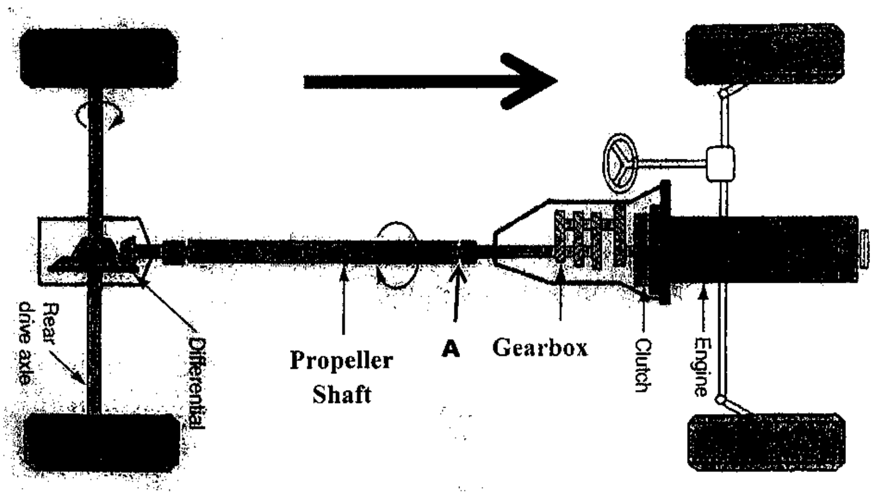

Figure 1: Transmission setup of a rear/four wheel vehicle

The transmission setup of the innovation is arranged to achieve more drawbar or pulling force from the drawbar power available for implement utilization or drawbar work. At position ‘A’ in Figure 1, a second gearbox is installed wherefore the Rpm at the first gearbox tail is further reduced before transmission to the axle and the tires. The velocity of forward movement ’v’ is drastically cut down enabling the achievement of great force for cultivation. The novel mini truck Tractor transmission setup is as shown in figure 2.

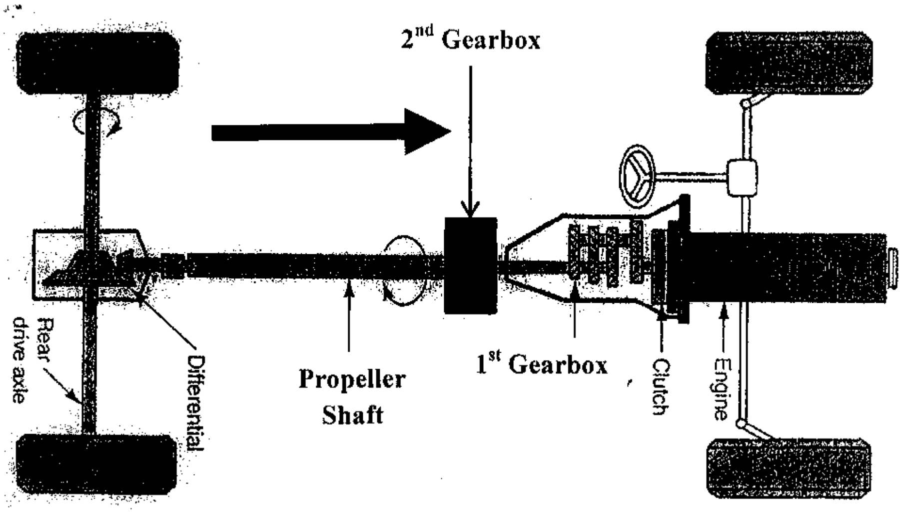

Figure 2: Transmission setup of the novel Mini Tractor

IX. Equipment Description

The innovation is set on a Land Rover or Range Rover or Pilot Jeep or anyrear or four drive high ground clearance vehicle employing manual transmission system and which for the purpose of agricultural farm utilization has a second gearbox or gear reducer installed in series with the first gear box wherefore the speed is further reduced by the cascade thereby achieving more drawbar force for pulling implements. It is employed mainly for farm cultivation with multiple plows.

The machinery is adapted to utilize animal drawn implements in executing farm operations. A mechanical hitch is also installed on the framework of the vehicle and operated accordingly. Figure 3 depicts the invention with mechanical hitch, while figure 4 is the Schematic diagram of Transmission system. Employing the specifications given in sections V, for the least power for Land Cruiser of 73 Kw at 2000 Rpm. The maximum draft to pull one animal drawn plow as reported by Loukanov et al., (2005) is 2000 N. From Table 1, the least available power for the implement following transmission and tractive losses is the one indicted for loose soil and given as 47.5% of engine power. Hence 47.5% of 73 Kw, equals 34.6 Kw. Thus theoretically the invention has 34.6 Kw to pull implements and can carry multiple plows if operated at the speed of work animals. Average animal speed equals 0.7m/s.

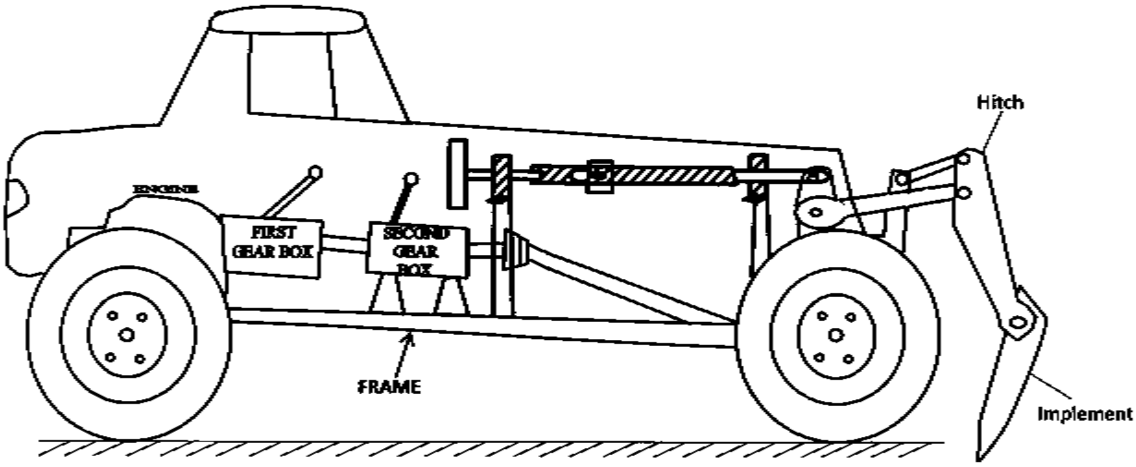

Figure 3: Schematic diagram of the Utility vehicle as mini tractor

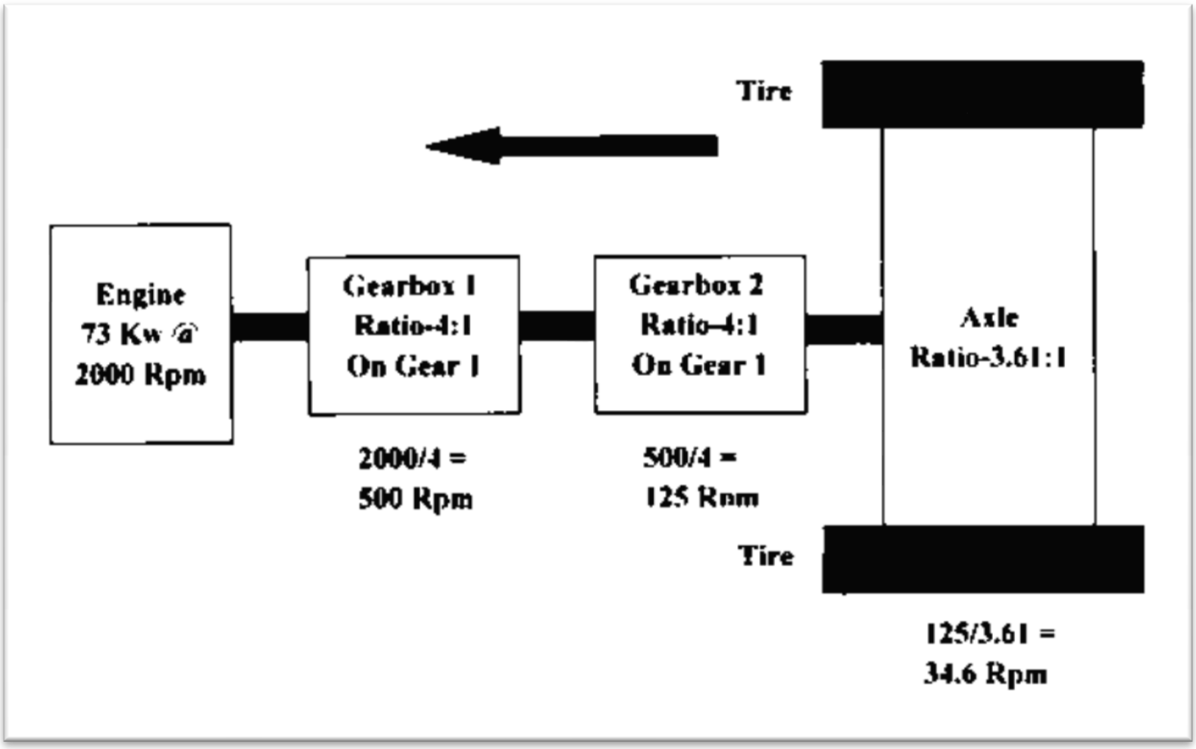

Figure 4: Schematic diagram showing the transmission system

Employing equations 3 and 4 and the tire diameter of 30inches (0.762m); the velocity v is calculated.

v = wr ------------------------------- (4) and from equation 3,

$$v = 2\pi N/60 \times r$$

$$v = 2 \times \pi \times 34.6 \times 0.381/ 60$$

$$= 1.38 m/s$$

Hence available draft for drawing implement using equation 1 is

$$34.6\ Kw = F \times v$$

Hence F = 34.6 x 1000 /1.38 = 25,000 N

Given maximum draft equals 2000 N. This implies that the invention can pull
25,000/1425

= 12 plows

X. Conclusion

There is food scarcity in Nigeria occasioned by unsuitable and poor agricultural mechanization especially with regard to cultivation. Since inception, our agricultural mechanization programme have been focused on tractor importation. But the tractors apart from being very expensive, lack available spare parts and specialized mechanics for maintenance. Their sizes are also beyond the proper capacity for optimal production in our small farm holdings. This work shows us that we can develop appropriately sized tractors to work our farms. The components for the manufacture of indigenous tractors shall be sourced from locally available technologies so that they can be easily maintained by our mechanics. The Power equation explains we can convert any cost effective road automobile in the country into a farm mobile power by reducing the speed to acceptable tractor working speed or animal walking speed. Draft of various cultivation implements and mobile farm powers from literature will guide the engineer towards developing appropriate tractors for use by Nigerian Farmers. Lots of automobiles have existed in Nigeria for decades. Theoretical computation shows a Toyota Land Cruiser utility vehicle can pull 12 plows implying that putting all physical and soil factors into consideration, the vehicle will conveniently pull 6 animal drawn plows. Their spare parts are found in every locality. Mechanics and artisans also abound who can easily repair and maintain the vehicles. It is believed that proper design and component selection would lead us to the development of appropriate indigenous farm powers that would match our need and farm fragmentation.

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