

Innovative Design of Tractor for Small and Marginal Farms Mechanisation

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ABSTRACT

Agriculture Tractors are widely used as prime mover either to pull or drive the "Implements" in the farms, apart from custom made equipments like Transplanter, Manure Spreader, Combine Harvester, Cotton Picker, mobile irrigation etc. which are used for particular operations in large production capacities. For larger landholdings, timely completion of the operation within the window period is the major decisive factor that drives agriculture tractor design. For small farms like in India, the productivity requirement was offset by the versatility of the equipment. Also, the farming practice varies in India due to geographical conditions such as soil types and demographic conditions such as crops types. Hence, the mechanisation level of matured market was not yet achieved in India, though the technologies are available for implementation.

In this present work, the need for innovative mechanisation solution for small and marginal farm is studied by comparing landholding trends and productivity requirements in comparison to matured market. A concept overview about innovative design of tractive equipment that could complement present day tractors in pulling agriculture-implements to do field operation for complete crop-lifecycle is discussed in a case study using TRIZ.

Extension of this proposed design could also automate the field operations and helps in precision farming of small & marginal landholdings. As the innovative design opens up low cost hybridization feasibility, the potential risks associated with agriculture tractor operations in terms of safety and pollution hazards could be minimized.

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INTRODUCTION

Globally, tractors are used to perform various agricultural operations. There are different implements designed to operate along with tractors for the field operations like, soil preparation, seed planting, weeding, nutrient & manure supplying, mobile irrigation, harvesting & baling. Self-propelled equipment designs meant for particular operations like harvester combines, cotton picker, balers, etc are in extensive use.

Study conducted in India reveals that currently the agriculture tractor is being used upto 45% to 56% for soil preparation and 40% to 45% for post-harvest purposes such as threshing and haulage while 3 to 5% used for planting purpose [1]. There is no specific equipment that could provide a complete mechanisation solution for Indian farm mechanisation needs.

In this present work, the major differences in the requirements of an agriculture tractor in India and saturated markets like United States have been studied. Also the unique characteristics of the equipment needed, to address the mechanisation solution for marginal farms are discussed. And finally an attempt is made to conceptualize the design of an alternate traction means that caters to small & marginal farmers' mechanisation needs in India.

GLOBAL RESEARCH WORKS IN AGRICULTURE MECHANISATION

Globally farm equipments matured enough to provide more than 95% mechanisation in agricultural operations. Hence, further research works focuses to improve the degree of automation, better ergonomics and increase in productivity. Tractors are being developed with more comfort using larger cab, ergonomic seat and controls, improved maneuverability with better steering characteristics and increased use of higher horsepower tractors and four wheel drive systems [2]. Research works are in place for auto guidance for tractors to avoid damages to crops while increasing productivity with less manpower. Using computers on-board together with satellite navigation systems, auto guidance to the farm tractors given by controlling the steering system to travel in straight row. Tractors are equipped with 'Precision Farming' technologies, to increase productivity and automation, by predicting tractor posture with respect the crop rows [3]. An attempt is made by Yas Takashima to develop Automated Vegetable Factory including with automatic harvesting to address the labor shortage in vegetable harvesting where hand operations are intensive and less mechanisation was achieved [4]. For the very high powered equipments alternate drive systems such as Electromechanical Drivetrain (EMD) etc were being experimented for driveline optimization and fuel economy [5] & [6].

While designs for “driver-less” tractors drives the research works for the future, currently farm workers are experiencing a very high incidence of injuries leading to physical and cognitive (strokes, Traumatic Brain Injury) disabilities. An attempt is made by Schuler and Novak with suitable adaptations in tractors to meet the requirements of the farmers with disabilities [7]. Safety is another focus area for agriculture tractors, which is based on creation of simulation models using steer angle, tire lateral forces, lateral acceleration, yaw rate and the side slip angle [8]. Another experiment is of developing a moveable balancing weight which addresses loss of stability and overturning due to heavy draw bar pull [9].

Studies conducted globally to understand the agriculture tractor operation in the fields for defining the engine exhaust emissions via regulative test cycles and also studies conducted to find different ways and means to meet these emission norms [10], [11], & [12].

Research works are also focused on developing implements to mount on tractors and power tillers like Independent PTO [13] and Coaxial Counter Rotary Tilling System [14].

Research Trends in India

There are improvement works taken up with respect to the noise and vibration in the cost conscious basic models of agriculture tractors. Research and development activities are focused on setting up test facility to identify the noise sources [15] and eliminating them at source or with passive techniques [16]. Whole Body Vibration Study by Pawar, S., et al along with calculation results exceeds the boundary set by ISO 2631-1 [17]. The steering wheel vibration could result in Hand-Arm Vibration Syndrome (HAVS) and requires isolation techniques to reduce it [18] & [19]. Footrest vibration was reduced by mitigating the natural frequencies upwards using isolation techniques and optimization of structural parts [20].

In an experiment conducted in India, there was very low level of correlation that could be established between on-road service conditions of an agriculture tractor, which is typical in India, to that of the official test procedure as described by international standard ISO 8178-4 [21].

The research works by Indian Agriculture Engineering organizations, resulted in improving custom made equipments, starting from improved hand tools for manual operation to self-propelled mechanisation solutions [22] that are different from global mechanisation technologies and specific to India. In India the technology trend is towards more tractorisation with extensive mechanisation in land preparation works using implements like ploughs, harrows and cultivators and some amount of mechanisation in harvesting majorly for wheat and rice [23] while other crops are not yet mechanized fully. The overall mechanisation level of agricultural operations in India is just 40% [24] only. Though the technology solutions of large farm sizes to do all inter-culture operations and plant protection methods are readily available, the problem arises when adapting them to the small & marginal farms of size less than 2 hectare.

The Problem of Small and Marginal Farms Mechanisation in India

Figure 1 depicts the trend of average farm size in US and India. The average size of farms in US is 429 acres, while in India the average farm size is 2.9 acres [25] & [26].

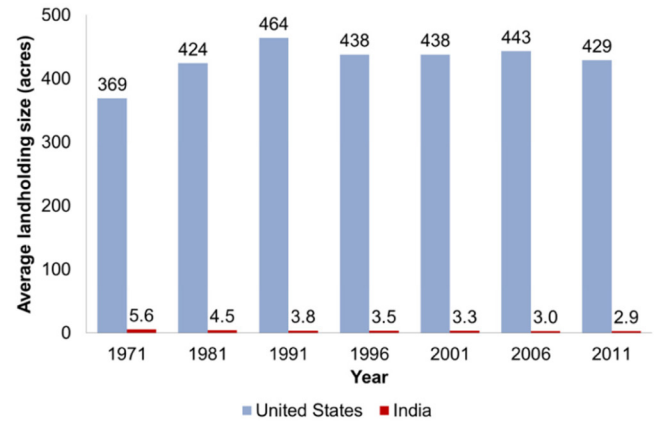


Figure 1. Land holding trend in US and India

Figure 2 depicts the % of farm numbers categorized by size. There are no farms in India of size greater than 50 acres, which is quite different when compared to US where 61% of farms are of larger than 50 acres. It is noted that 95% of total farms in India are small farms of less than 10 acres in size while in US, 89% of farms are of more than 10 acres in size.

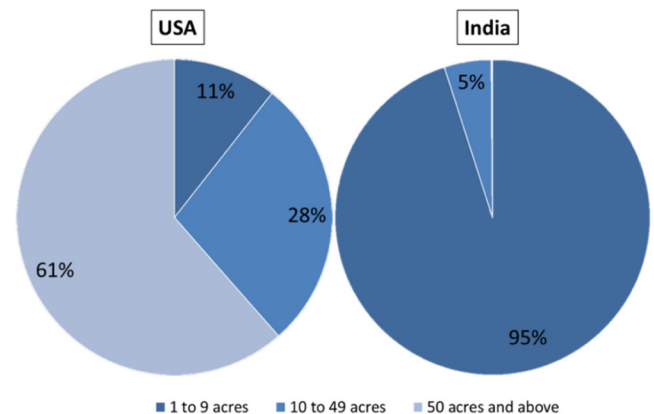


Figure 2. Farms number by size of farm

There is difference in productivity requirement from farm equipments as applied to these two different farm sizes. For example, productivity required for a harvest operation with 30 days window period for corn and 14 days window period for wheat are shown in Figure 3, as applied to the two extremes of average landholding sizes, India and US.

In large farm holdings as in US or Europe, a \$300,000 combine harvester used only for 4 weeks per year to ensure TIMELINESS. Productivity described by the speed with which the operation shall be completed within the window period. However, in India, such high power machine is uneconomical as the average landholding size is less than 1% as that of in the highly mechanized countries.

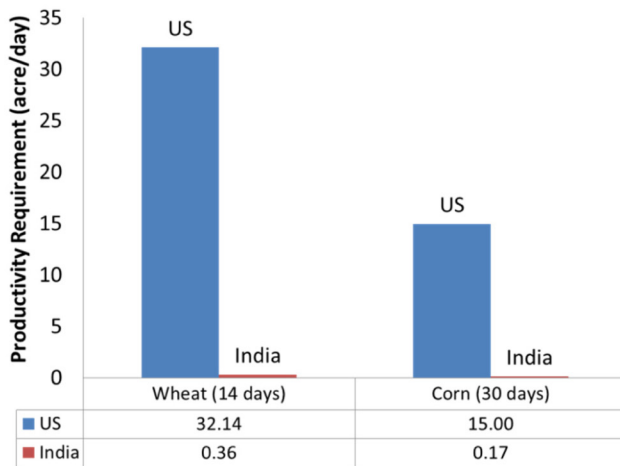


Figure 3. Harvesting Window and average Farm Size (US & India)

For a machine to be an economically viable solution in India, it should be used for more than 1000 hours per year to meet the “minimum scale of operation” [24]. India produces varieties of crops, in different types of soil conditions under varying climatic situations. Research works succeeded in developing implements for seeding and planting of few specific crops (less than 5%), while large percentage of crop varieties is still untouched by mechanisation. The crop protection activities like weeding, nutrient supply and irrigation are still remaining as un-mechanized and labor intensive. As the level of mechanisation particularly depends on scale of operation and average size of farms is less than 3 acres, it is inevitable to have a single VERSATILE farm machine that could be useful for all agriculture operations including inter-culture and plant protection activities, to increase the mechanisation level further, in India.

Since the current mechanisation solutions mostly based on tractors and power tillers were restricted from inter-crop and plant protection activities, 84% of Indian cultivators are kept away from mechanisation. The farm equipments possessed by small and marginal farmers are substantially less than medium and large farmers. The Indian farm equipment industry is challenged with finding appropriate technology to address mechanisation needs of small and marginal farms of India, where the farm size is below 5 acres' [23] & [24].

The economics in large farms of matured markets depends on machine productivity improvement, while in small & marginal farms; the economics of operation depends on universal usability of farm machine. There are restrictions in universal application of the operation specific product technologies from matured markets, to the small landholdings in India, due to narrow rows crop cultivation methods.

The tractors characteristics dimensions such as wheel track and ground clearance leads to crop loss if tried to use for all agricultural activities. In rice cultivation, about 40% of current cultivation area has to be given up to allow even the smallest tractor, available in India, to pass through. For crops planted with larger gaps also, this tractor cannot be used for inter-culture operations, as the crop grows 4 to 8 times above the ground clearance of the tractor, which increases potential crop loss, when pass over.

INVENTIVE PROBLEM SOLVING THRO' TRIZ

The technology solutions meant for higher productivity rate that already exist in matured markets, do not address the unique need of small & marginal size farms in India, which requires universal utilization factor. While utilizing the tractor universally for all agriculture operation, the crop loss is inevitable. To address such technology riddle without any fuzzy methods, TRIZ is used as a systematic approach to evaluate the opportunities for future technology [27]. TRIZ is a Russian acronym for Theory of Inventive Problem Solving, which describes principles of innovation and creativity that are extracted from an analysis of over 2 million world-wide patents. Several leading companies in US, Japan, Europe and Korea were used this methodology to develop many new products and technology innovations. One of the TRIZ tools is based on the hypotheses that the problems and solutions repeated across industries. By learning these repeated general patterns of problems-solutions, number of resolutions for the technical contradictions of specific problem shall be created in a scientific way [28] & [29].

TRIZ algorithm (Figure 4) was followed to achieve the goal of universally adaptable mechanisation solution for small and marginal farms of less than 5 acres in size.

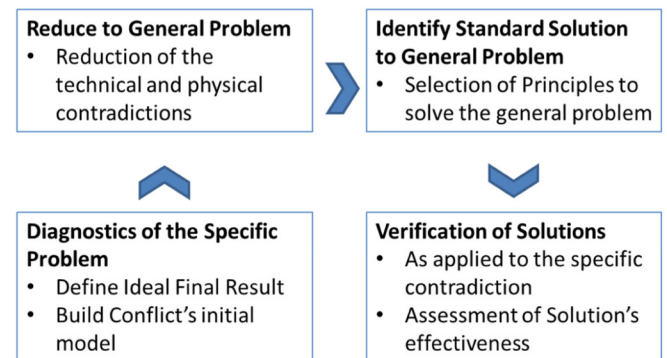


Figure 4. Meta-Algorithm of Inventing [29] as applied to the specific problem of small for mechanisation

Diagnostics and Reduction of the Problem of Small Farm Mechanisation

The Ideal Final Result

The Ideal Final Result of a farm equipment design would be that it caters to all agriculture operations

1. Primary & secondary tillage of soil
2. Sowing / Planting
3. Intercrop operation, like weeding
4. Plant protection operation like pesticide spraying, manure spreading
5. Irrigation activity, like watering the plants
6. Harvesting & threshing operations

The progress of moving towards this Ideal Final Result is called as “Ideality”, expressed by the equation