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Research Paper

A mobile, *in-situ* soil bin test facility to investigate the performance of *maresha* plough

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Ethiopia is well known for its use of an *ard* plough dating from antiquity – *maresha* – which fractures and disturbs the soil. However, hardly any notable progress of experimental research on this animal drawn tillage tool in the field has been made. The attendant problems in current practise are soil-*maresha* interaction, viz., uneven oxen strength along with different pace of walking, uncontrolled implement behaviour, and field conditions. Taking stock of the experimental research on animal drawn tillage tools in general, most of the documented works on the dynamics of the interaction between soil and animal drawn tillage tools tend to rely on trial-and-error based on factors mainly based on experience and cultural context. As such, no research tailored to systematically handle the link between *maresha* plough and soil bin experiments exists.

To this aim, this study developed a mobile *in-situ* soil bin facility in which the system was calibrated, tested, and evaluated under outdoor experimental conditions, wherein online measurements of draught, speed, and depth of tillage were carried out.

The insights and observations gained from the experimentation were discussed and reported in terms of smooth run, overload, cyclic forces, zero speed with minimal force, stoppage, speed measurement with no force, force measurement with no speed, and low speed with low force.

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Acronyms and glossary of local term

ASAE	American Society of Agricultural Engineers
ASME	American Society of Mechanical Engineers
DBK 43A	8-channel strain gauge module
DF	Dongfeng, tractor model from China
FAO	Food and Agriculture Organization
FUTA	Federal University of Technology, Akure, Nigerai
IMAG	Institute of Agricultural and Environmental Engineering (Instituut voor Mechanisatie, Arbeid en Gebouwen)
LVDT	Linear Variable Displacement Transducer
NTML	National Tillage and Machinery Laboratory
SQB-SS	Single-ended shear beam load cell – stainless steel construction
VLIR	Vlaamse Interuniversitaire Raad Flemish Interuniversity Council (an InterUniversity co-operation Programme of the Flemish Inter-University Council)
Ard	In French means 'pointed head', and a name given to animal drawn implement
Maresha	Traditional plough in Amharic

Notations

a	location at which plough shank welded with the ploughshare
b	location of area of centroid of *maresha* plough assumed coincided with the centroid of the distributed load area – soil resistance.
c	location of pinned connection of plough shank on the steel frame
d	location of centre of lower hole of the load cell
C	vertical projected distance of 'L_{ab}'
D	tillage depth
α	rake angle
L_{ab}	length between point 'a' and 'b'
$L1$	distance from point 'a' to 'd'
$L2$	distance from point 'd' to 'c'
$F_{Load,\ Resistance}$	load representing assumed equivalent concentrated load, soil resistance on Plough (equivalent to draught force – F)
$F_{Load\ Cell}$	force transferred to load cell
V	tillage speed

1. Introduction

The onset of harnessing on draught animal power to augment man's physical efforts in tillage dates back to the beginning of sedentary life and agriculture. Rolling down to the present system of agricultural crop production, motive power for crop production, harvesting and transportation has been provided by humans, draught animals, and motors/engines in various proportions (FAO, 2003; Pearson, 2005). In developing countries, about 80% of the power input on farms is provided by draught animals and humans (Pearson, 2005). Schmitz (1990) estimated that animal drawn ploughs of various types have been used by about 75% of farmers in North and East Africa, South-East Europe, the Near and Far East and Latin America.

Notwithstanding the growing contributions of tractor power to land preparation, animal traction is believed by many farmers, researchers, and policy makers to be an appropriate, affordable, and sustainable technology requiring few internal inputs (Bobobee, 2007). As such, the use of animal traction technology as an alternative farm power source for tillage in much of the Sub-Saharan Africa region is projected to continue (FAO, 2001) on account of its specific merits mainly due to: (1) the adjustable width of the ox-team, which is valuable in different types of cultivation, and the possibility to use oxen even in wet soil conditions, with lower cost of animal traction (Henriksson & Lindholm, 2000); (2) its relative simplicity and regenerative character, strong indigenous character, and simple support systems (Gebresenbet et al., 1997a,b); (3) the cost of spares, poor training of operators, and inadequate back-up service escalated by the rising costs of maintenance for modern machinery, making motorised machinery uneconomic even for contractors (Kaumbutho & Ithula, 1990; Kaumbutho & Mwago, 1993).

Prompted, in large part, by advantages, and alluding to "the past failures of tractor mechanisation projects in many developing countries" (Bobobee, 2007), there is renewed interest in research on the overall dynamics of the interaction between soil and animal drawn tillage tools. Ethiopia is well-known for the use of an *ard* plough – *maresha* – which fractures and disturbs the soil and dates from antiquity. However, hardly any notable progress in terms of experimental research on animal drawn tillage tool in the field has been made concerning current practice and the attendant problems of soil-*maresha* interaction, viz., uneven oxen strength along with different pace of walking, uncontrolled implement behaviour, and field conditions.

Most documented work on the dynamics of the interaction between soil and animal drawn tillage tools tends to have been reliant on trial-and-error procedures based on experience and cultural context. Apart from limited research work on animal drawn tillage tools in general, no research particularly tailored to systematically handle the link between *maresha* plough and soil bin experimentation exists.

Here, the gaps in experimental research works on animal traction tillage tools are discussed. And, taking into account soil variability and financial constraints, an experimental approach on the dynamics of soil-*maresha* plough interaction using a mobile and *in-situ* soil bin test facility was developed. Hence, this paper aims to: (1) describe the development of a mobile *in-situ* soil bin testing device; and (2) report the observations and insights gained from the field experiments.

2. Soil bin test facility

At the broader level, research to gain a better insight into the soil-machine/tool continuum can be via the evaluation of soil-tool interaction through mathematical modelling (mechanics) or by experimental analysis (Onwualu 1991). However, soil-tool tests are usually determined using experimental methods and are conducted either by performing field testing or in laboratory soil bin facilities. In the case of full-scale field