Indian Farming 75 (11): 27-30; November 2025

Cut-soiler-preferential shallow subsurface drainage (PSSD):

A novel technique of salinity management with no residue burning

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Soil salinization is a major cause of land degradation in irrigated areas, often reducing productivity and forcing field abandonment. Salinity build-up in the root zone results from saline irrigation, shallow groundwater, weathering, and poor drainage. Conventional measures such as leaching and drainage installation have limitations due to high cost and technical constraints. A novel method, cut-soiler based Preferential Shallow Subsurface Drainage (PSSD), offers an effective alternative. The tractor-operated cut-soiler uses surface residues as filling material to construct shallow (40–60 cm) drains that promote preferential removal of water and salts while simultaneously managing residues without burning. Cut-soiler was introduced in India under Japan International Research Centre for Agricultural Sciences (JIRCAS)-ICAR-Central Soil Salinity Research Institute (ICAR-CSSRI) collaborative research project. The findings of evaluation studies on salt removal effect of cut-soiler PSSD suggested that it can reduce soil salinity upto 60% in a semi controlled lysimeter simulation study and upto 50% in the field condition in three years. The subsequent effect of desalination on performances of tested crops is prominent and consistent. Unlike conventional subsurface drainage, it is low-cost, farmer-friendly, and can be applied at the individual farm level, making it a promising option for sustainable salinity and residue management.

Keywords: Cut-soiler, Drainage, PSSD, Salt affected soil, Salinization

THE Sustainable Development Goals emphasize the need to enhance food production, restore soil and ecosystem health, improve water management, and address climate challenges by promoting the multifunctional use of natural resources within their ecological limits, thereby preventing further land degradation. Among the major drivers of desertification and land deterioration, salinization is regarded as a critical environmental threat, leading to both ecological imbalance and economic losses. The problem of salt accumulation in soils and water bodies has become a major barrier to sustainable agriculture, particularly in arid and semi-arid regions, where it restricts crop productivity. Globally, salt-affected soils are distributed across more than 100 countries, covering an estimated 835 million hectares of which 438 million hectares are sodic and 397 million hectares are saline. In India, approximately 6.7 million hectares are classified as salt-affected, while 32–84% of groundwater resources are considered unsuitable due to poor quality.

In India, salt-affected soils have been present since time immemorial but recorded evidences are available only after middle of 19th century when salinization started adversely affecting crop yields and economic well-being of people and system ecology. The problem has origin in natural processes as well as secondary human induced factors. Presently the salt-affected soils exist in fourteen states and one union territory of the country. In the coming years, the extent of salt-affected soils is likely to expand due to factors such as secondary salinization in canal command and lift-irrigation areas, greater reliance on poor-quality water in semi-arid and arid zones, seawater intrusion driven by climate change, and the growing practice of brackish water aquaculture in coastal regions.

The challenge of salinity is becoming more severe, particularly in poorly drained soils with high salt content. Addressing this issue requires a practical, farm-level technology that individual farmers can easily adopt. The cut-soiler approach, which provides a low-cost preferential drainage system, offers a promising and economical option for the long-term management of salt-affected soils.

Overview of cut-soiler

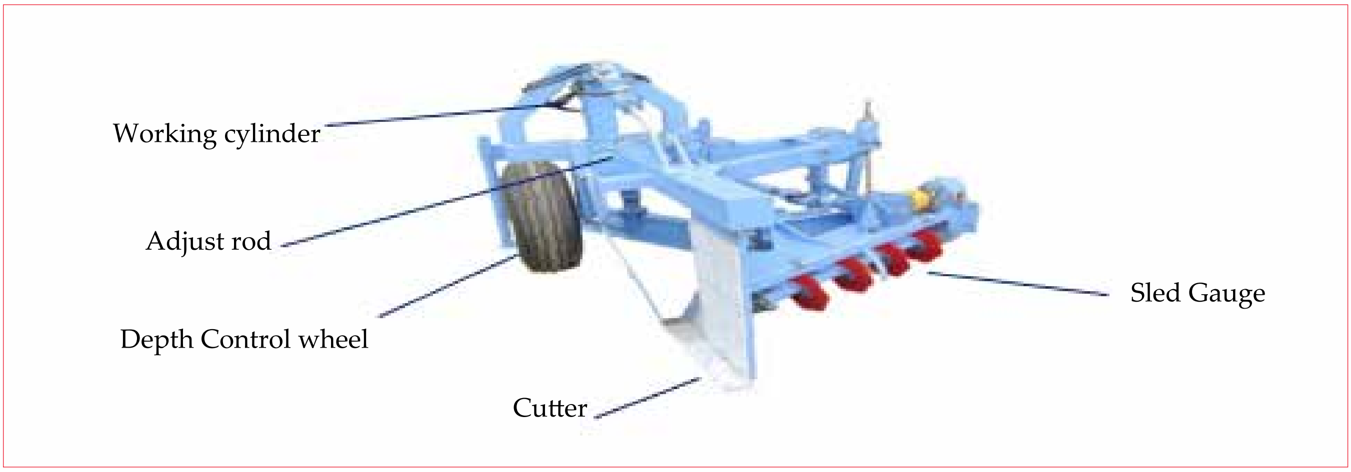
Development background and history: The cut-soiler is a tractor-operated implement designed to utilize surface residues such as straw, stems, and other plant remains to create preferential shallow subsurface drainage (PSSD) channels as it moves across the field. This system simultaneously addresses the dual challenges of waterlogging and salinity while providing an effective means of residue management. The drainage channels function through water flow, generally about 60 cm deep, and exhibit discharge efficiency comparable to conventional main drains. The technology has been successfully applied in practice, and farmers can establish these drains quickly and conveniently without requiring specialized materials.

Cut-soiler has been developed and put into commercial use jointly by National Agriculture and Food Research Organization (NARO) and Hokkai Koki Corporation, Japan (Patented in 2017). Cut-soiler was introduced in India under JIRCAS and ICAR-CSSRI collaborative research project on sustainable resource management system for waterlogged and saline arid regions of India. The project envisages evaluation, utility and standardization of this approach on salt leaching and nutrient dynamics in the field and lysimeter conditions.

Features and specifications of cut-soiler: It is mainly consisted of cutter blade and sled gauge. The cutter is working like a chisel plough that cut and lift the soil to open up space to insert filling material. The sled gauge is a whirling shaft that hard sweeps the surface residue and places it into the space opened by cutter. The cutter shaft is slightly slanting in such a way that the lifted soil filled back in the open space over the filling material (residue) without inverting the soil. The working cylinder is provided for the hydraulic lifting movement using tractor power. The depth control wheel is to control the depth of drain constructed by cut-soiler. The specifications of the cut-soiler along with its tractor power requirements are dimensions (LxWxH): 2.0 m x 1.5 m x 1.65 m and weighs 800 kg. following are some recommendations:

- Tractor capacity required: 60–120 HP
- Recommended operating speed: 2–3 km/h
- Material treatment: maximum 10 cm length
- Construction depth: 40–60 cm

Operation mechanism of cut-soiler: The cut-soiler operates by cut the soil to create a V-shaped furrow. During this process, the soil is lifted, and surface residues



Cut-soiler machine

Cut-soiler operation in the field

Mechanism of cut-soiler operation for preferential shallow sub-surface drainage construction

such as straw and plant material are placed at the base of the furrow before the excavated soil is returned. These constructed lines act as shallow subsurface drainage channels, effectively reducing surface waterlogging and mitigating soil salinity. The accompanying figure illustrates the working mechanism of the Cut-soiler in establishing these drains.

Cut-soiler can also place the soil reclamation amendments like gypsum along with residue at sub-surface and thus a practical technique to reclaim sub-surface sodicity. Cut-soiler can manage the complete surface rice residue (upto 6 t/ha) by placing it to sub surface in a single tractor operation, hence an effective tool to reduce the residue burning problem of rice-wheat belt of IGP.

Precautions during construction of cut-soiler PSSD

- To maintain the desired lateral distance between drain lines and enhance water and salt outflow, the tractor should be run straight in the direction of the natural slope.
- The filler material, such as crop residue, should be evenly spread on the ground and preferably be 8–10 cm in size. The larger size residue can clog, disrupt the consistency of cut-soiler action, and diminish the tractor pulling capacity.
- To ensure uniform depth of cut-soiler constructed drains, the field should be laser leveled with a 2% slope oriented toward the main drain, the tractor should operate at constant slow speed (2—4 km/h) and the PTO (power take-off) rotates continuously.
- The quality of the straw/residues utilised determines stability and durability cut-soiler drain. However, channels made with rice straw residue were effective for around three years.
- The recommended lateral spacing between two adjacent cut-soiler drainage channels ranges from 2.5–5.0 m. (depending on soil type and field conditions).
- Each cut-soiler lateral drain must linked to the main drain line to lay off drained water from the field.
- In case of placement of reclamation amendments into soil sub-surface, the amendment (Gypsum) should spread homogeneously over rice straw after cutting it into finer lengths using the mulcher.
- It is advisable to adjust the depth of the cut-soiler drains by depth control wheel before running in the field according to the depth of sodic layer presence or required depth of drainage.

Advantages

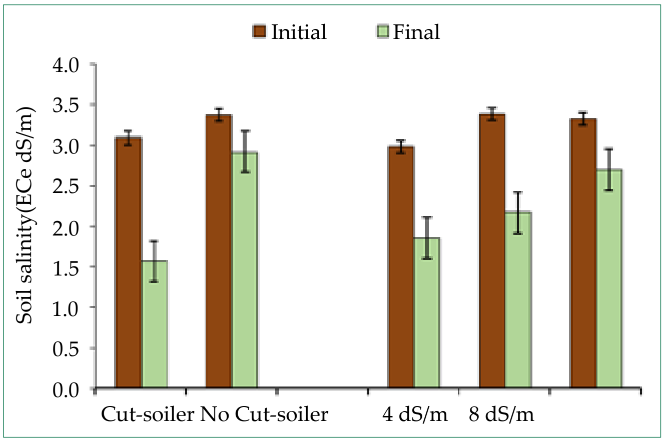
- Cut-soiler PSSD construction does not require any extra material of machinery, hence, it is low cost in operation and no requirement of large area or community approach as it can be used by individual farmer.
- It uses surface left over surface scattered residue after combine harvest as filling material, so may help in reducing residue burning.
- Placing crop residues at the base of the cut-soiler furrow contributes to carbon sequestration and enhances overall soil health.
- The cut-soiler drains being shallow, helps in reducing drainage effluent volume.
- It is a viable technique for the placement of reclamation amendment at sub surface, so helpful in managing sub-surface sodicity.

Limitations

- Higher tractor power requirement.
- Requirement for additional hydraulic point in tractor for better lifting.
- An initial hand on training is required for operating, handling procedure, functions, and precautions during the operation.

Pilot studies on performance evaluation of cut-soiler PSSD

Studies at ICAR-CSSRI, Karnal, demonstrated the effectiveness of cut-soiler based PSSD in lowering soil salinity through a semi-controlled lysimeter setup where drains were constructed manually. Results showed that this system decreased soil salinity by 50–60% within two years across different soil types. The extent of desalinization varied depending on soil texture, the quality of irrigation water, and seasonal rainfall patterns. The PSSD facilitated greater discharge of excess water and dissolved salts immediately after irrigation and rainfall events. Notably, irrigation water with salinity levels up to 8.0 dS/m could be applied without causing



Effect of cut-soiler PSSD and varying saline irrigation water on soil salinity reduction over two years

additional salt accumulation. Improved soil conditions, combining lower salinity with favourable moisture availability, enhanced crop performance. In pearl millet, grain yield increased by 23.54% and biological yield by 12.64%. Similarly, mustard showed yield improvements of 31.4% in seed, 14.41% in straw, and 18.08% in biological output.

The effectiveness of cut-soiler PSSD in salt removal and salinity management was also proved in the field validation trial at representative salt affected site at village Nain (Panipat), Haryana. In this study, upto 52% reduction in soil salinity (ECe) was recorded with cut-soiler PSSD at 2.5 m lateral interval. In this study, cut-soiler drains were installed at a depth of 60 cm, with rice residue applied as a filling material at the rate of 6 Mg/ha. The system resulted in a 50% increase in mustard yield. Moreover, it was observed that irrigation water with salinity levels up to 12.0 dS/m could be utilized under this drainage method without contributing to additional salt accumulation.

A field experiment was carried out in Bhudhmor village (Patiala, Punjab), where the cut-soiler machine was used to place gypsum and rice residues at different lateral intervals for reclaiming by 23.77%, 14.92%, and 5.95% at lateral spacings of 0.30 m, 0.60 m, and 1.25 m, respectively. When gypsum and rice straw residues were incorporated at a depth of 40 cm crop productivity also improved under this system, with rice and wheat yields showing increases of 16% and 15.5% at 2.5 m spacing, and 6% and 10.7% at 5.0 m spacing, compared with the control treatment (without cut-soiler intervention).

SUMMARY

The cut-soiler PSSD presents a promising approach for managing both soil salinity and surface residues. This preferential subsurface drainage system offers a practical solution to minimize salt build-up and can be implemented at the individual farm level in a single operation. Unlike conventional subsurface drainage, it does not require heavy machinery, high investment, collective participation, or the complex handling of large volumes of saline effluents. However, additional research is necessary to clearly establish its long-term influence on soil water and salt dynamics, as well as its economic feasibility under different soil textures, varying irrigation water salinity, and diverse types of crop residues, to ensure sustainable management of salt-affected soils.

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