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CA-Mechanization Transitions

--- Moving From Manual to Mechanized CA Cropping ---

by John E. Morrison, Jr, PhD Agricultural Engineer
Adjunct Professor, University of Tennessee, USA
109 Laurel Lane, Unicoi, TN 37692 USA, morrison@mounet.com

Summary:

Smallholder village farmers are typically introduced to conservation-agriculture (CA) with manual field operations. After this first introduction and demonstration period, mechanized animal-draft procedures may be introduced for those smallholders with access to draft animals. Alternatively, tractorized mechanization may be introduced if draft animals are not available, or if agricultural advisors have provided convincing arguments and demonstrations that given the local situation, tractorization is appropriate for their situation.

Both animal-draft and tractorized mechanization of CA-cropping field operations may require a reevaluation of recommended cropping practices and field management. This is because regardless of the power source (animals or tractors), field implements must be operated across the field in a reasonably–consistent manner to accomplish the required tasks. In contrast, when using manual CA field cropping practices, each operation is a step-by-step procedure which can avoid obstacles, irregularities in the soil surface, rocks, and/or piled or otherwise tough and unruly old-crop residues. Therefore, for mechanized CA, appropriate field procedures must be identified for CA field and cropping conditions which are consistent with the principles and goals of CA.

This is a discussion of technical situations encountered in the field, aside from most economic, cultural, agronomic, or other considerations.

Situation:

With manual CA-cropping field operations, the farmers can walk, seed, apply fertilizers, apply agricultural chemicals, hoe-control weeds, and harvest without regard for field irregularities, existing plants, and obstacles. When those farmers transition to mechanized field operations, whether animal-draft or tractorized, there must be available traffic paths for each operation and all soil-engaging implements must function through old-crop residues, killed weeds, applied FYM, and/or other beneficial materials that have been applied to the soil surface. Therefore, some different CA-cropping methods/practices and management alternatives may need to be introduced to be able to continue abiding by CA principles and achieving the CA-cropping goals of each farmer, in response to changes in the tools and power sources employed.

Problems and Possible Solutions:

A) Residue management

Problem: Residue management is a major consideration with mechanized-CA. For example, with manual-CA, tall stalks, weeds, etc. can be slashed and randomly strewn on the field surface for soil protection. Crops can be manually seeded into such residue-covered soils by use of various digging tools, “jab planters”, dibble sticks, etc.

with general abandon. Such field conditions may provide soil protection consistent with CA principles and low-disturbance seeding practices, but present challenging situations for the use of any soil-engaging mechanized-CA implements which must be capable of consistently clearing and cutting row paths through such old-crop residues. Providing soil protection year-around is a basic tenant of CA, so that the more residue cover that can be produced by crops and retained on the soil surface, all the better for subsequent CA crops. But, CA mechanization implements that interact/engage with the soil must be adequate to pass through such residue soil cover to control weeds, plant seed, apply fertilizers/nutrient materials, etc.

Solution: If the CA crops have been grown under irrigated conditions, then it is likely that a high amount of old-crop residues have been grown and it will be extremely difficult to utilize field machines with passive residue path clearing devices. Unless a portion of the residues are removed for off-field uses or cut/chopped into short lengths, some type of powered row-path clearing devices will be needed on CA implements.

If the CA crops have been grown under dryland/rain-fed conditions, then the remaining stalks, stubble, and other residues will often be adequate to provide effective soil protection, but not prohibitive for the use of passive (non-powered) row-path clearing rakes, etc. Additionally, improved field conditions can be provided by leaving old-crop stalks standing, so that they do not need to be cut by the row-path clearing devices on the CA machines. CA farmers soon learn that it is preferable to make new row-paths beside or in the middles between old-crop rows to minimize the amount of stubble and other residues that must be cleared from new row-paths.

If "green-manure", dense, or viney crops have been grown, then these crops and/or their residues should be given adequate time to deteriorate before attempting to seed a new crop with low-disturbance CA-cropping methods and machines. Crops for such purposes should be chosen so that the resulting old-crop residues do not provide "impossible" field conditions for mechanization.

B) <u>Preseeding Weed Control</u>

Problem: CA crops are seeded into untilled soil, but this does not mean that there should be any live plants or plant roots in the field when the new crop is seeded. Just as tangled residues on the soil surface may impede acceptable functioning of mechanization implements (A, above), so can live roots from a previous crop or from recently slashed/cut plant growth. This problem is a common occurrence in CA field demonstrations, wherein the field is not properly prepared to commence CA seeding operations. Such demonstrations are negative training for the attendees of demonstrations as to how to prepare fields for successful CA seeding. Unproductive grasses, weeds, and any other vegetation which grow between cropping seasons utilize valuable soil water supplies and nutrients. Additionally, if old-crop stubble and/or weed growth has not been completely killed, then regrowth of those plants will be growth-competition for the new crop.

Solution: All vegetation must be thoroughly killed prior to the CA seeding operation. This requires appropriate management and inspection to insure that the herbicidal weed control is conducted in a timely manner and that it has been effective. The ideal situation is to maintain a "stale seedbed" between cropping seasons, wherein there will be no vegetation growth of any kind. The soil surface and the stored soil water will be protected by the old-crop residues and any other protective materials applied on the surface during this "fallow" period.

C) <u>Soil Condition</u>

1) **Wet or "Problem" Soils Problem:** With the use of manual CA cropping, field operations in wet or "problem" soils can be conducted at almost any time and especially so when the soil is densely covered with old-crop

residues, so that manual mobility is not a factor. Seeding into highly-wet soil is rarely recommended, but it can be physically accomplished with manual operations. Seeding-related soil engagement into hard, dry soils by manual or machine methods is limited by the available energy and/or appropriate machine design to do so. Some problem soils are "hard-setting" due to the particular ratio of sand, silt, and clay particles and this situation is enhanced by the lack of adequate organic matter from years of traditional cropping.

Conversely, for mechanized CA field operations, soil condition is important or even critical when operating in most important soil-types for cropping. Machine mobility is enhanced by the presence of surface residues and the fact that the soil has not been loosened by plowing. Machine mobility is a main consideration for non-soil-engaging operations, such as the spraying of agricultural chemicals and above-ground harvesting. For soil-engaging operations, such as seeding, fertilizer applications, and mechanical weeding, in addition to machine mobility the soil must be in a condition which will be compatible with the tools being used and the desired outcome of the operation. Degraded field soils may be in difficult conditions for the use of mechanization when the transition is started from traditional cropping to CA; this situation can result in more stringent machine-function requirements during the first CA cropping seasons than after CA has been established.

Solution: Luckily for CA cropping, soil engagement is typically only a few centimeters deep, which supports the goal of low-disturbance. Also, as CA is continued year-after-year this surface layer of soil typically becomes more highly organic, less adhesive, and more friable.

Soil-engaging mechanization tools are typically more successfully used in drier soils than in wet soils. Also, the old-crop residues lying on drier soils tend to also be drier and more successfully cleared from row paths than tougher high-moisture residues lying on wet soils. Soils that are wet enough to adhere to machine tools will typically smear, compact, and cause machine blockages.

A useful guideline is that if soil collects on the treads of the tractor tires, then the soil is too wet for seeding or other soil-engaging operations. For monsoon climates, crops can be dry-seeded at the end of the dry period, or seeded after the first rains when the soils have become moistened down to a depth of approximately 15 cm, but not saturated.

2) **Old-Crop Residues Problem:** Having old-crop residues distributed across the field surface produces the condition of the surface soil being drier in the open/exposed spaces between pieces or groups of residues than the soil under the residues. Therefore, the surface layer of soil will not be at a uniform water content, which may cause the soil-engaging tools used for mechanized CA to sporadically produce different results as the machine passes across the field.

   Solution: The CA farmers must wait for surface soil drying after rainfall until acceptable conditions are reached for both exposed and protected soils before performing mechanized CA field operations. Such waiting periods should not be critical because in the non-plowed field conditions of CA cropping, the necessary field operations are conducted in very short time periods, minimizing any potential effect on crop growth and yield.

D) <u>Field Topography</u>

Problem: In some regions, smallholder farms will be predominately located on highly sloping landscapes. There are at least four main problems with the use of mechanized field procedures on such fields. The first problem is that CA field operations should be conducted across the slopes to minimize soil erosion and water run-off losses, rather than up-and-down slopes as traditionally practiced in many regions. The second problem is the potential safety hazard of machine overturning or cascading out of control down-slope. The third problem is the difficulty to turn a field machine at the end of a crop row on highly sloping lands. The fourth problem is that many agricultural machines tend to slide sideways down-slope when operated across-slope, and that this is especially true when operating on "slippery" residue-covered soils.

Solution: Agricultural advisors must determine the maximum field slopes on which mechanized CA cropping can be practiced and include this in their training programs. Fields with slopes in excess of such maximums should be relegated to the use of manual CA methods and practices.

E) Applied Materials

Problem: The traditional technology of "incorporating" surface-applied materials with tillage is not compatible with the low-disturbance principles of CA. This would typically be the broadcasted application of FYM, calcium/lime, or other materials, followed by some type of broadcast tillage operation to mix the applied materials into the surface layer of soil.

Solution: With CA cropping, all materials applied prior to seeding of the new crop are broadcast on the surface of the field. For FYM and other nutrient-rich materials, these add protective residues on the surface and their nutrients leach into the soil with infiltrating rainfall. For calcium/lime and such soil amendments, the minerals also leach into the soil, and principally into the rooting zone with rainfall for effective crop utilization. This is effective because the protective residues covering the soil surface prevent soil-sealing, so that rainfall water infiltrates in situ, effectively incorporating beneficial constituents without the need for traditional incorporation with tillage.

F) Cropping Patterns

1) **Broadcasted Crops:** Broadcasted crops are seeded by a general distribution/spreading of seed across the field surface. Traditionally, such broadcasting of seed is followed by shallow harrowing to incorporate the seed into the surface soil. For relay cropping, seed may be broadcast into a growing "host" crop for final growth and harvesting after the harvesting of the host crop, and will not be incorporated into the soil, but germinates on the moist soil surface.
2) **Drilled Crops:** Drilled crops are seeded in rows typically spaced 15-25 cm apart, with the seed metered into the rows at a bulk rate and not singulated. Typical drilled crops are wheat, dryland rice, barley, and some beans, sorghums, and millets.
3) **Row Crops:** Row crops are seeded in rows typically spaced 60-100 cm apart, with the seed being either bulk-metered or singulated for uniform plant spacings. Typical row crops are maize, sorghum, sun flowers, cotton, ground nuts, beans, etc.

Problem: When using manual cropping methods, smallholders can use various inter-cropping schemes, such as seeding one crop into another established crop ("intercropping" and/or "relay cropping"). Typical examples are beans, squash, or melons seeded between or into rows of maize or other tall crop for intercropping. Or, a relay crop is seeded into an established crop for growth and harvest after that of the host crop. Such manual procedures are possible (and, possibly reasonable) because field workers can seed the second crop without injuring the original crop. Weeds may be manually cultivated/hoed within the crop plants and the growth of weeds may also be reduced by shading within the multiple crop canopies [we must recognize that all of these advantages may be true for low-population "traditional" crop stands which will not develop a full crop canopy; in such cases, the seeding of a second inter-crop may add crop plants to obtain a more full canopy and utilization of the field area for increased total production/yield].

The inter-crop may provide some N fertilization to the host crop, so that there may be real advantages to intercropping, especially when N fertilizers are not readily/economically available. But, the inter-crop will compete with the host crop for soil water and nutrients, so that the individual yields of both the host and inter-crop will be compromised/limited by the competition. When full crop stands are achieved for the main crop with improved seeding methods, and when crop growth is enhanced by adequate crop fertilization, there may or may not be potential synergetic effects to produce real increased total crop yields from the use of such intercropping methods. The inter-crops are individually harvested by manual methods. When we transition to mechanized methods, all of the above considerations need to be reviewed to determine when/if intercropping or relay-cropping is advantageous enough to justify the time and costs of needed developments of new implements and field procedures. Such implements are not currently available.

Solution: Available mechanized methods and implements are basically designed to be used for mono-cropping. Using strips of monocrops is suggested for mechanization.

G) <u>Crop Fertilizer Applications</u>

1) **Depleted Soils Problem:** Soils in many smallholder-cropping regions are being systematically depleted because more soil nutrients are being removed by crops than are being replaced by applications of fertilizers. The resulting lowering soil fertility will not produce enough old-crop residues to provide protective soil coverage for successful long-term CA practice.

   Solution: Agricultural advisors must include fertilization training with their demonstrations and introductions of CA to smallholders.

2) **Underperforming GMO Seeds Problem:** Expensive GMO seeds are being promoted, but the low rates of fertilization used by many smallholders will not justify the use of these seeds because their benefits will not be sufficiently/economically expressed at low to moderate levels of crop management.

   Solution: Use selected open-pollinated seed for early introduction of CA cropping and to produce valid comparisons with the benefits of CA against traditional cropping methods.

3) **FYM Incorporation Problem:** FYM is traditionally broadcasted on the soil surface and incorporated into the surface layer by use of tillage, but such tillage would violate the principle of low-disturbance for CA.

   Solution: FYM can be broadcasted onto the field surface to provide additional soil-protective residues and nutrients to leach into the crop root zone. Incorporation tillage is not necessary with CA because the nutrients will leach in situ into the soil due to the soil surface remaining permeable to rain water infiltration.

4) **Starter-Fertilizer Application Problem:** Starter-fertilizers are known to be beneficial for the early growth of many crops, but for mechanized seeding the addition of starter fertilizer application devices, which are soil engaging, add expense and complexity to seeders for CA field conditions. Traditional recommendations for plowed-soil systems are to deposit the starter fertilizer materials 5 cm below the seed and 5 cm to one side of the seed location in the soil. Such recommendations and application devices typically cause additional soil disturbance and unending technical problems when seeding into non-plowed residue-covered soils.

   Solution: Limited (non-toxic) rates of starter fertilizers and trace minerals may be metered into the seed furrow with the seed for many crops. The usual recommendation is that all of the phosphorus (P) in the form of P_2O_5 for the crop needs will not be toxic to the germinating seed and can be safely deposited into the seed furrow. Nitrogen (N) and potassium (K) may be toxic if applied above tolerated rates [example: the usual recommendation for maize grown as a row crop is a total of N+K of 15-20 kg/ha]. Experience and caution should be used when recommending rates of starter fertilizers to be deposited into the seed furrow. For strip-till (row-ripping), starter fertilizer may be applied a few cm below the seeding depth and fertilizer toxicity may not be critical. In CA field conditions, using CA seeding machines which meter starter fertilizers directly into the seed furrow minimizes soil disturbance and provides the minimum of complexity, cost, and technical problems.

5) **Fertilizer Application Problem:** For most crops there is a positive economic return for the investment in applied fertilizers. But, when non-plowed cropping practices are introduced, the most common method of applying granular fertilizer materials has been to manually broadcast fertilizers onto the soil surface. When such methods are utilized with CA cropping, a portion of expensive N fertilizer is wasted by negative activity in deteriorating both protective residue materials and valuable soil organic matter in the surface layer. Additionally, urea-based N fertilizers may become volatile and lost to the atmosphere. Broadcasted K fertilizers are relatively non-mobile, predominately remaining in the surface layers above the root zone.

   Solution: The most efficient/effective method available for application of granular fertilizer materials is to apply the materials in concentrated bands beside crop rows. For drilled crops, this must be a surface application between the rows, but benefits remain for the concentration of materials in bands [this is usually done with bands applied between pairs of drilled rows]. For row crops, furrows may be opened beside early-stage crop plants, "sidedressing", to deposit the materials beneath the highly-organic surface layer for the most efficient utilization of expensive fertilizers by crop plants. Sidedressing must be done, possibly earlier than traditional practice, so that the crop is not too tall to be damaged during the application operation.

H) <u>Weed Control (During Cropping Season)</u>

Problem: Agricultural fields typically have weed seed buried in the soil. This "seed bank" in the soil must be depleted. Therefore, it is very important to accomplish weed control during the first few years of CA cropping. With conventional tillage, a portion of these seed are brought near the surface to germinate each tillage season. Fortunately, with low-disturbance CA cropping there are fewer buried weed seed germinating than with plowed soils. Unfortunately, even the minimal soil disturbance caused by mechanized soil-engaging tools will support the germination of weed seed in those disturbed strips and such weed growth not controlled by the shading and competition of the crop canopy must be physically controlled to prevent seed production.

Solution: The farmers must not grow weed seed. Weed growth between crop plants within crop rows must be "controlled" (not allowed enough growth to produce seed), as well as in the middles between crop rows. This will require a high level of management to assure success. Weed control will typically be accomplished by use of both manual hoeing and the application of herbicides. For between crop row applications, "hooded/shielded/directed" herbicide sprayers can be pulled between rows to kill weeds and reduce the amount of manual hoeing required for successful weed control during the cropping season. As reported, the amount of cropping land that can be successfully utilized by a smallholder highly depends upon the maximum area which can be successfully weeded.

I) <u>Harvesting</u>

Problem: If mechanized harvesting is to be conducted on CA fields, then intercropping cannot be practiced, unless the earlier-maturing crop is manually harvested so that mechanized harvesting can used for the second crop. If relay cropping is practiced, then as for intercropping, some scheme of combing manual and mechanized harvesting may be needed (unless the relay-crop is immature enough to not be harmed by the passage of a mechanical harvester for the host crop).

Solution: For mechanized CA cropping, it is much easier to manage crop harvesting if the crops are grown as mono-crops in field strips rather than as inter-crops or relay-crops.

Remarks:

We realize that even for smallholders, there will be a range of appropriate field cropping procedures as they adopt/adapt/transition to CA-cropping from traditional procedures. Also, we realize that when CA is accepted/established as the new standard for crop production, over time those same smallholders may move up the ladder of sophistication, such as from manual to animal-draft or tractorized procedures. Further, we understand that it will not be uncommon for a mixture of farming methods to be employed which may include manual and mechanized procedures. Therefore, agricultural advisors will need to be prepared to guide such farmers so that they are able to successfully maintain their following of the principles of CA while using new or different power sources and implements.

For animal-draft CA-mechanization, field implements will be similar to those used for tractorization (below), principally differing in size, hitching means, and lift and transport schemes. This similarity is because the same field functions need to be performed, regardless of the power source.

For tractorized CA-mechanization, we believe that we have the support of many action agencies, NGOs, and agricultural-development specialists in identifying 2-wheel tractors (2WTs) as the least expensive and most economical tractor power units for use by smallholders (typically <2 ha of crop land). To that end, CA implements are being developed, demonstrated, and provided as attachments for 2 WTs. Complete tractorized cropping systems are visualized as being equipped with a 2WT (8-16 Hp), broadcast-type field sprayer, 1 or 2 row CA-seeder for row crops (rows spaced 60-100 cm apart) and/or 4, 6, or 8 row CA-drill for drilled crops (rows spaced 15-25 cm), sidedress banding-type fertilizer applicator, directed/shielded herbicide sprayer for herbicidal weed control between crop rows (row crops), harvester or harvesting-aide, and transport trailer/cart.

Contact Information:

The author is working with Stone Mountain Technologies Inc. (SMTI), StoneMountainTechnologies.com, to manufacture the *Morrison Seeders®* CA-Seeder 1000, and with World Help Through Technology Foundation (WHT), WHTFound.com, to establish world-wide distribution. Distribution for USA and Canada to be announced. The author is continuing to refine his designs of a full line of appropriate field implements for smallholder CA-mechanization, e.g. DAT tow, broadcast sprayers, and shielded sprayers. Further information is available at MorrisonSeeders.com and Seederinfo@WHTFound.org

As we strive to get these tools into the hands of those who can best benefit from them, we are seeking regional distributors/dealers to provide demonstration, sales, service, and parts for currently-available and future CA implements. Please use the contacts above for inquiries.