Importance of zero-tillage with high stubble to trap snow and increase wheat yields in Northern Kazakhstan [1]

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Summary

In the northern part of Kazakhstan, zero-tillage[2] technology has the potential to increase wheat/grain productivity by 20 to 50 percent above current levels. However, phasing out conventional tillage can only be gradual, as full conversion to zero-tillage will require important investments and farm organizational changes. Actual current area under conservation agriculture (CA) appears to be increasing significantly every year, and is now estimated to be 1.2 million hectares. The country has, in the medium-term (3-5 years), the capacity to adopt conservation agriculture on about 30-40 percent of the cereal cropped area (3 to 4 million ha) with adequate investment. The possible average production increase from this achievement could be of about 1 million additional tonnes of wheat annually. In the longer term, wide adoption of CA technology would bring a global benefit by contributing to improved carbon storage, which would also have a positive effect on climate change due to decreased greenhouse gas emissions. The World Bank-financed Agricultural Competitiveness Project, which is being assisted by FAO's Investment Centre Division, is supporting CA expansion through its Competitive Grant Scheme. Continued support and increased emphasis could contribute to improving food security and the overall cereal and grain production system competitiveness (increased production at lower costs).

1. Conservation Agriculture (CA) includes zero-tillage as a farm technology, which in Northern Kazakhstan allows higher crop yields than conventional tillage but at a reduced per-ha cost of production. This brief note refers to CA as the combination of the following three principles: (a) continuous no-till which allows leaving high stubble standing (also creating soil health conditions that in the medium to long term defeat weeds); (b) permanent soil cover; and (c) crop rotation. Zero-tillage also enhances optimal soil biological, chemical, and physical features (including moisture retention). However, this technology requires important investments and farm organizational changes as described below.

2. The agro-ecological conditions of Northern Kazakhstan and the scale of agricultural enterprising are such that true no-till and enhanced snow-trapping[3] have become the best opportunity to increase wheat yields and production[4]. After long-term experiences of soil conservation technologies recommended since Soviet time as a means to combat land degradation and heavy soil erosion, the agricultural production system is now speedily moving in the direction

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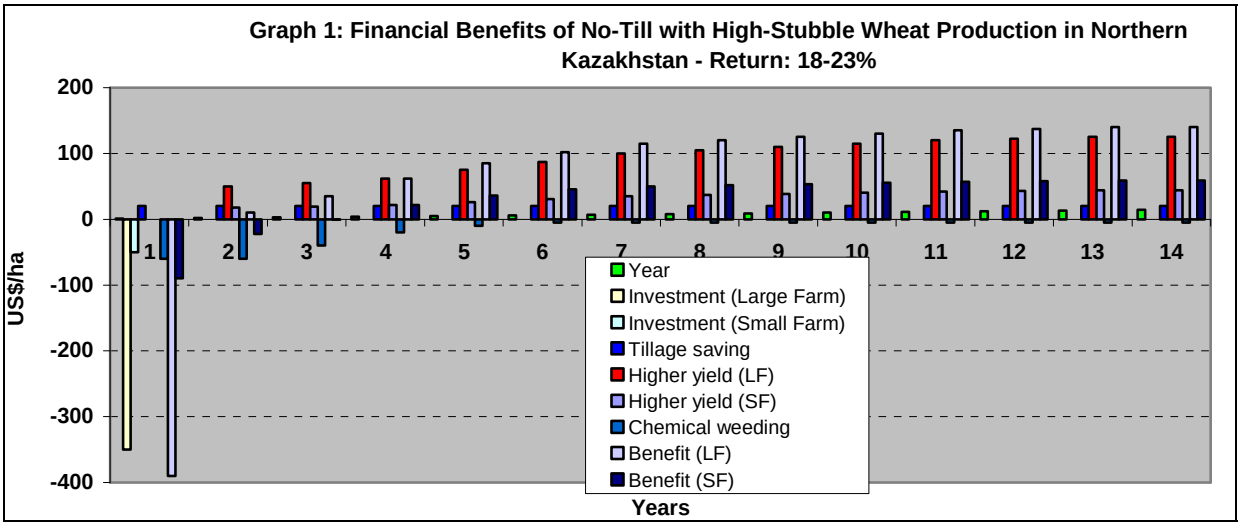
[1] This note is the result of two missions by an FAO senior agronomist (Turi Fileccia, Investment Centre Division) to Kazakhstan in June 2008 and April 2009. The missions interacted with the World Bank-financed Agricultural Competitiveness Project (ACP) project coordination unit (Ayup Iskakov); officials of the Ministry of Agriculture (MOA, Anna Buts); researchers of the Barayev Grain Farming Research and Production Centre (B-GFRPC, Kanat Akshalov); researchers of the International Maize and Wheat Improvement Center-CIMMYT (Murat Karabayev, Pat Wall, Mekhlis Suleimenov, and Arman Baitassov); Nikolai Ushenko of the Karaganda Research Centre for Crop Production and Breeding (KRCCP&B); officials of Kazhydromet (Ludmilla Chuntonova, Irina Kalyamova); and, among others, the chief agronomists and farmers in the Akmola and Karaganda oblasts (Novokubanskoye Farm: Nadejda Baraeva; Phoenix Farm: Denis Pluzhnik; Dostick-06 Farm: Meyram Sagimbayev). The views expressed are those of the author and do not necessarily reflect the views of the institutions named.

[2] Zero-tillage is also known as no-till or direct seeding

[3] Snow-trapping is also called snow-harvesting or snow-capturing

[4] Conservation agriculture research work and experiences in Kazakhstan have involved the B–GFRPC, FAO and CIMMYT since 2000 (see also http://www.fao.org/tc/tcp/kazakhstan_en.asp; http://www.cimmyt.org/english/wps/news/2006/mar/sympTraverses.htm and http://www.icarda.cgiar.org/cac/publications.asp?id=3

of no-till. A number of progressive farmers are trying to gradually phase out traditional tillage but more investment is required to change the system. These have been encouraged by the positive financial rate of return, which is estimated at a respectable 18 to 23 percent.



3. The current cropped area under reduced tillage technologies is reported to range between 5.5 and 7.5 million hectares, but the majority of this area is actually considered to be experiencing minimum-tillage techniques. Nevertheless, researchers and practitioners estimate that zero-tillage area is increasing fast from an estimated area of around 600 000 ha in 2007 to about 1.2 million ha in 2008 (see Table 1). This tremendous progress has been acknowledged and communicated by FAO during the World Summit on Conservation Agriculture held in New Delhi in February 2009[5]. The huge increase appears to be due particularly to wide adoption rates in large farms in Northern Kazakhstan (with cropped areas of over 50 000 ha, but including farms of 0.4 to 0.6 up to one million ha each)[6]. Investment-oriented and innovative large farm managers have been driven to adopt zero-tillage after appreciation of yield performance and cost reduction results and also because of wheat price hikes which started in 2007. However, such significant progressions cannot be considered stable and withdrawals, especially of 'smaller' farms (from 5 000 to 30 000 ha), back to minimum/and also in extreme cases to tilled fallow/conventional tillage may still be expected.

5 A number of initiatives are now targeting the expansion of CA technologies also in the south of Kazakhstan, including zero-tillage under irrigated conditions. CIMMYT is about to start a new programme in southern Kazakhstan to apply CA under irrigated (permanent raised beds) and rainfed conditions; other technologies include drip irrigation and agro-forestry. Financial supporter will be the Japanese Tobacco Institute (JTI) and Gallaher (under its Corporate Social Responsibility policy) with USD 1 million per year for two to three years to be implemented in Almaty, Zhambyl, and Kyzylorda oblasts. They intend to target small farmers with about 100 ha each.

6 CIMMYT (Astana) indicates that in 2006 the actual zero-tillage area in Kazakhstan was estimated (through some remote sensing verification) at around 120 000 ha; this area moved to about 0.6 million ha in 2007. In July 2008, CIMMYT (through its Academician M. Suleimenov) made a survey in North Kazakhstan, Kostanai, and Akmola oblasts. Interviews with large farmers, field visits and verification of numbers of available modern direct seeding machinery allowed the following estimation of area under zero-tillage: 612 000 ha (16 percent of sown area) in North Kazakhstan; 400 000 ha (over 9 percent of sown area) in Kostanai; and 180 000 ha (over 4 percent of sown area) in Akmola.

Table 1: Wheat area and productivity estimates under different technologies adopted in Northern Kazakhstan

Area	***2007***	***2008***
Traditional Tillage	13.7 million ha	11.5 million ha
Minimum Tillage	4.6 million ha	6.1 million ha
No–till	0.6 million ha	1.2 million ha
Productivity	***Without Snow–Trapping***	***With Snow–Trapping***
Traditional Tillage	0.8–0.9 t/ha	n.a.
Minimum Tillage	n.a.	0.95–1.2 t/ha
No–till	n.a.	1.25–1.9 t/ha

Source: CIMMYT (Astana) and mission elaboration.

4. The main obstacle to the adoption of the zero-tillage technology seems to be the organizational capacity and the type of mechanical equipment available with 'small' and 'medium'-sized farms. Farmers want to plant the maximum area possible; the seed drills and combine harvester machinery that are commonly available actually limit the area that can be cropped under no-till conditions. In addition, there are a number of technical problems tied to appropriate herbicide management; increased occurrence of below average precipitation years (which also decrease production of crop residues and stubble effectiveness); inclusion of rotational crops; and importantly, availability double disc/narrow chisel openers attached to the direct seeding drills. Finally, abandoning tilled summer fallow in favour of other types of rotation requires significant technological and mindset changes which are difficult to achieve. All such issues, which require further research work, innovations, and investment, constrain full and permanent adoption of proper zero-tillage technology in Kazakhstan.

The importance of soil moisture

5. The single most important factor that determines grain/wheat yield in Northern Kazakhstan is moisture. Soil moisture depends on precipitations and in Kazakhstan snow accounts for 35-40 percent of all precipitations. Annual average precipitation in major wheat-producing areas (Akmola, Kostanai, and North Kazakhstan, where about 80-85 percent of Kazakh wheat is produced[7]) ranges from 250 to 350 mm. Hence, an efficient and full use of all precipitations is crucial. When snow is captured on the soil in a manner that allows it to melt gradually, it brings a two-fold advantage: more moisture is available along the arable soil profile (the more water is able to percolate, the deeper it is distributed[8]) and at the same time, erosion is reduced or even eliminated.

6. Snow-trapping is a known and practiced technique in Kazakhstan. Historically, snow accumulation was done only through mechanical means by using 'ploughs' to shape snow mounds. This technique is costly, requiring fuel, machine-operating cost[9], and wear and tear. It also does not mitigate (or significantly reduce) runoff induced erosion.

7. Alternatively, another technique is to capture snow on the field by trapping it through residual plant stubble. About eight years of on-farm research results show that ideal snow capturing levels coupled with no-till technologies enhance other intensive technology inputs and are able to increase yield by 58 percent (from 1.2 to 1.9 t/ha). It has also been shown that mechanical snow-

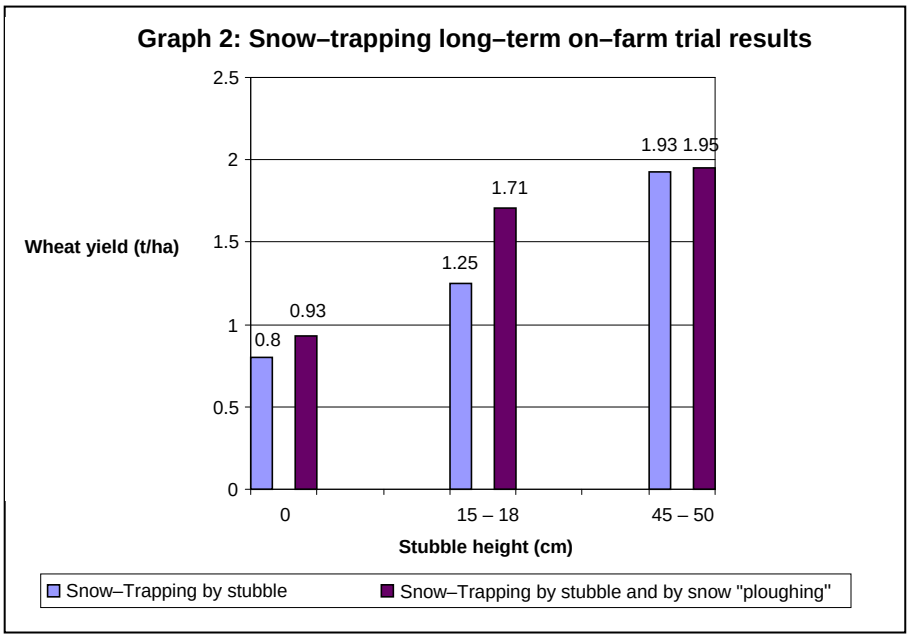
[7] Overall wheat area in Kazakhstan ranges between 10-12 million ha while production amounts to 8-10 million tonnes, annually.

[8] Trials accumulating 30-40 cm of snow through 45-50 cm of stubble have shown availability of 120 mm of water along 1 meter soil depth.

[9] At a cost increase estimated around USD 15/ha.

trapping coupled with stubble capturing brings no additional benefits, while mechanical harvesting alone (without stubble) increases yield by only 17 percent (see picture and chart).

Figure 1: Snow trapping through residual stubble



8. No-till technology typically provides cost savings in soil preparation because there is no need to plough or cultivate the soil before sowing. However, for the first few years, this technology requires high use of herbicides, which offsets the soil preparation cost savings. In addition, herbicide use and the sowing period in Northern Kazakhstan may involve time-conflict issues on large farm areas. This represents, at current farm organizational conditions, an important obstacle for full technology adoption. After four to five years, weeds decrease considerably and herbicide

use diminishes and eventually ceases. In addition, the technology does not allow tilled fallow; instead rotation with a crop other than wheat is required, a requirement that is not easily acknowledged by farmers. Only after this transition period the technology is altogether financially and environmentally beneficial[10].

9. Considering both the cost savings and the yield gains, the economic efficiency of wheat production with no-till technology results in an average improved net profit per ha of over 50 percent[11]. However the transition period described above makes the tillage (and fallow) mentality 'hard-to-die'. This can be changed only through wide demonstration and dissemination (and farmer acknowledgement) of the opportunities offered by practicing true CA, which the Competitive Grant Scheme (CGS) under the ACP is well suited to facilitate.

Opportunities and limits under current conditions

10. Snow is trapped by standing stubble, which is available only under zero-tillage technologies; otherwise, even under minimum tillage conditions, it is reversed by the autumn till (during fallow years)[12].

11. The other key factor for wheat crop success in Kazakhstan is sowing time. The time-window for this operation is extremely limited by the particular climatic conditions. In Akmola, the available time is from 15 May to 3-4 June. Before this date, the soil is too moist, and/or thaw is incomplete. Afterwards, the soil dries and moisture availability reduces and the plant will not fully exploit the precious spring precipitations. In the absence of fall tillage and until no-till techniques have been completely established (providing all foreseen benefits, mostly decreased weed presence), chemical weeding is compulsory. The timing of this operation must be around 18 to 20 May after weed germination has occurred, otherwise treatment is ineffective. The required time interval between chemical treatment and sowing depends on available machinery and implements. Generally, the existing seed drills and equipment (carrying traditional hoes with "V" type opening shoes), require an interval of about 10 days (which may reduce in dryer years) without vegetative growth to effectively kill the weeds. This limitation constrains the sowing time to 4 to 7 days, obliging farmers (particularly the large farms) to limit the area that can be organized under no-till accordingly.

12. Trials of chemical treatment of weeds done after sowing have proven unsuccessful as the seed drills tend to cover the weeds and herbicides become ineffective. This is because the

[10] Farmers' experience at present no (/minimum)–till practice conditions allows for yield gains in the range of 20 percent. Although there is a potential of significant per–ha cost of production savings (reductions over 30 percent), for the time being farmers' costs of production are either the same as under conventional tillage or decrease only by 10-18 percent. Actually, at the very beginning when management is not optimized yet, costs may even increase by 10 percent. In addition, Kazakh farmers practice repeated wheat cropping and normal crop rotation is largely disregarded: up to seven years of continuous wheat cropping is not unusual which is generally interrupted by one year of tilled fallow (with 4 to 5 tillage operations through sub–soiling) with fertilization (one time for the entire "rotation"). Some farmers have started to introduce pulses in the rotation (peas, chickpeas) and other cereals, and are also reducing the interval. Successive wheat growing is interrupted after 5 to 7 years with one year of tilled fallow to which most of the input (N and P fertilizers) and operations investment is made. Typically, after fallow the land is used to produce quality seed. During the early technology establishment stages herbicide use cannot be avoided. After four to five years weeds decrease considerably and only 1-2 litres of Glysophate is required (instead of 2-4 litres at the beginning).

[11] Conservation Agriculture for Sustainable Crop Production in Northern Kazakhstan, MOA, FAO and CIMMYT, 2002-2004.

[12] In order to get the best advantage of snow melt a good soil structure is needed which in turn allows for optimal permeability and water holding capacity. Proper conservation agriculture techniques gradually re-generate appropriate structure conditions of soils that have been destructured by sustained tillage.

'tillage' effect of the 'V' shoes of traditional sowing equipment reduces effectiveness of herbicides[13]. However, seed drill hoes that have been modified by progressive farmers cause less soil disturbance and thus herbicides can complete their action on the weeds. This shortens by about two to three days the interval before direct seeding can be initiated. These adaptations constitute an improvement that should be up-scaled and adopted by small/medium sized farmers who want to pursue technology transition to no-till. The cost of such adaptation to traditional seed drill units (e.g. of KAZAKHSELMASH type) is in the range of USD 10-15 000 for a direct seeding unit capable of working 120-130 ha on a 24 hrs basis[14].

Figure 2: Traditional seed drills commonly used in medium and large farms of Kazakhstan, V-type and modified drill-hoes.



13. Alternatively, modern double disc opening seed drills allow for sowing even three days after herbicide treatment, enabling in such a manner about 8 to 12 days sowing period. To have a comparable working capacity to the traditional ones, the required investment is in the range of USD 150 000-200 000[15]. Seed drills, which have a higher working capacity[16] (200 ha in 24 hours)

[13] Some farmers (in drier areas of Akmola) who claim to have major weed issues, also state that they defeat weeds more easily by pre-sowing mechanical weeding (with chains mounted on the back side of the seed drills) being however obliged also to chemical post-germination weeding because Glysophate pre-sowing treatment is not sufficient. For this reason they maintain traditional tillage and tilled fallow technology as a means for weed management and soil moisture enhancement. Emergence of major weed problems have been frequently cited as a problem associated with no-till farming. This issue has been overcome whenever rotation is followed. There has been herbicide resistance now for a long time (see for example: http://www.weedscience.org/summary/MOASummary.asp), and there are several examples of successful weed management in continuous zero-tillage, without escalating herbicide costs or sky-rocketing rates.

[14] Such seed drill units (a 14 meters sowing area width requires a group of seven sets each having nine drills that are chain-pulled by a tractor of 235 Hp/St. Petersburg make) would allow for 1-1 500 ha direct sown area with a ten-day sowing time window. Realistically, the current operational capacity of the farmers may not allow for more than 60 percent of full capacity (750 ha). The number of available operating units in one farm also determines the overall area which can be managed under no-till technology.

[15] E.g. seed drills of Amazone, Crucianelli, and other makes.

rule out a number of problems. However, these machines are expensive (K$ 360-400), requiring powerful tractors (380-450 Hp) and are accessible mainly by large organized farms[17]. The required investment for modern disc opening seed drills and stripper headers on combine harvesters (see below) is assumed to be at USD 250-350 per ha for large farms and USD 50 per ha for smaller farms in machinery (to be repeated after 15 years)[18]. The financial rate of return is estimated at a respectable 18-23 percent.

14. Conservation agriculture is the condition to have standing stubble every year and a healthy soil which is able to best exploit the available moisture. However, what mostly determines the quantity and persistence (and gradual melting) of snow that is captured is the height of preceding crop stubble.

15. The height of the stubble, in turn, depends on the level at which the combine harvester's cutting bar is set to cut. The majority of the varieties grown in Northern Kazakhstan are semi-dwarf with plant height of 50 to 70-80 cm. The shorter varieties and poorer plant performance (depending on precipitation) limit the harvesting cutting level. Managers and combine operators fear grain losses during harvesting. Reportedly, grain losses by leaving the stubble 30 cm high, are in the range of five percent as compared to two percent when cutting lower. However, even under typical conditions and with the majority of the available varieties it is possible to leave on the field stubble of appropriate height (35-40 cm) through more accurate harvesting operations. These probably require more carefulness, skilful operators, and good maintenance of the harvester cutting blades. Old combine harvesters also limit the benefits of snow-trapping as these, at present conditions, do not enable raising the cutter more than a certain height thus reducing the stubble height to a maximum of 30 cm, and generally at 25 cm, though not everybody agrees with this statement. In any case, it is better to have five percent losses with a yield of 1.5 t/ha (1.42 t/ha) instead of two percent losses with a yield of 1.2 t/ha (1.17 t/ha). An interesting alternative would be to adapt the modern combine harvesters (available among the majority of large farms in Northern Kazakhstan) with stripper type headers[19] that remove the spikes while leaving behind taller stubble than left by conventional platform headers.

16. Further area-specific as well as farm category-specific investigations are required and should be made available to farmers for their informed decisions. Research institutes are carrying out on–farm trials to determine variety performance[20], responses of different seed drill machinery

[16] E.g. John Deer 18-90 type mounted on 450 Hp tractors.

[17] The BARAYEV Center (jointly with MoARK, KazAgroInnovation and Amazone) is conducting trials on a number of wheat farms in different agro–ecological conditions. The direct seeding machineries that are being tested include MORRIS and Amazone CITAN-Z. The Citan-Z has also been coupled with an Amazone CATROS cultivator. Trials have been performed in the Rodina Farm (Akmola) with different sowing rates (114, 103, and 86 kg/ha) and at diverse sowing dates (14 May and 24 May). Results show that with Citan-Z drilled wheat germinates better and with healthier stands (because seed is drilled shallower at 3.5 cm instead of 6 cm depth); later sowing at lower seed rates is more successful; and fuel consumption is lowest. Although winter precipitation was 75 percent of average and spring precipitations as low as 40 percent of average, yield was still above 0.8 t/ha with 103 and 86kg/ha seed rates (respectively 15 percent and 23 percent higher yields). Yield performance of Citan-Z decreased however by 17 percent with higher seed rates (but with 10 percent more seed).

[18] Farms that must modernize their machinery park and need to invest also on modern combine harvesters would require a higher investment estimated at USD 350/ha.

[19] E.g. stripper headers of Shellbourne Reynolds make (approximate cost: USD 40-50 000). These are still under experimental use in Kazakhstan with mixed results up to now.

[20] Varieties being on-farm tested for behaviour under both conventional and no-till+snow capturing techniques include Akmola-2; Astana; Astana-2; Tselina-50; Tselinnaya-Yujanka; Shorthandy-95; Pamyaty Movchana; Baitiriek; Rosinka-3; Omskaya–28; Omskaya-31; Svietlanka. Many of such trials are being supported by the ACP through the CGS. The Tsileno-50 variety (released by the Barayev institute in 2008) is being multiplied for wider adoption as it has a higher plant stand while yield and quality are also very good.

makes, best sowing dates, optimal seed rates[21], rotation crops, and different fallow type performances[22]. Farmers, with the assistance and support of the research institutions, are also testing varieties that yield grain of best required technological quality and that at the same time perform better under no-till technologies. Research topics that may be useful and that have been probably insufficiently investigated would regard, for example, weed treatment timing and required interval before sowing with traditional and modified seed drills; and means to mitigate evapotranspiration losses caused by the strong spring winds.

17. **Mulching**. Soil moisture is enhanced by mulch made out of crop residues permanently left on the soil. Mulch, combined with high stubble, also improves snow-trapping. However, crop residues need to be well chopped and evenly spread, otherwise the efficiency of hoe-type seed drills during sowing operations is decreased. Straw chopping may be done separately (with additional cost and equipment) or during harvesting through adequately equipped combine harvesters. Modern combine harvesters (K$ 300-350, operational capacity: 50-80 ha per day) have the option to include straw choppers. Old combines, like the YENESEI commonly used in Kazakhstan (operational capacity of about 25 ha per day; price of new around K$ 100), require some adaptation to include the operation.

18. **Zero-tillage economics**. The advantages of zero-tillage adoption are clear, particularly in Northern Kazakhstan as shown by the sky-rocketing area increase under the technology. Adoption is easier by large farms that have better organizational and technological structures and are capable of heavy investment in a very short time. However, 'smaller' to 'medium'-sized farms (that in northern Kazakh standards include farms of 5 000 to 20 000 ha), which make the bulk of the wheat-cropped area, require location- and size-specific adaptation measures. Many measures are being made increasingly available through the on-farm work of the major research centres even if these require wider dissemination. A single most important judgement element for informed decision by farmers would regard the economics of zero-tillage. The advantages of zero-tillage need wide dissemination together with comparative information on required capital investment, costs of production, and financial returns that are associated with the different techniques, inputs, and production methodologies (seed rates, sowing time, herbicide, rotation crop, fallow, mechanical weeding, snow trapping)[23].

[21] Organized large- and medium-scale farms use and produce quality seed either under license conditions (those that are authorized to sell) or not (those that multiply seed for their internal farm needs). Such farms use seed of Elite category down to 2nd-3rd reproduction and sell (those authorized) 2nd, 3rd and 4th reproduction. Seed rates used are quite high ranging from 100 kg to 160 kg per ha depending on the quality of the seed. Spring wheat seed rates are calculated in terms of number of seeds per ha and range from three million to 4.5 million seeds per ha (@ 33-34 grams per 1000 seeds). Given the low average yields of Kazakhstan (0.8-0.9 t/ha) high seed rates become a real issue.

[22] The Karaganda Research Centre in collaboration with CIMMYT has tested a number of fallow systems (1. traditional tilled fallow; 2. tilled fallow and chemical treatment for weeds; 3. only chemical treatment; 4. chemical treatment and sowing of residue creating oat-crop; 5. double chemical treatment with reduced seed rate of residue creating oat-crop) on land that had been abandoned for more than 15 years. The fallow was followed by a wheat crop and trial results show that when wheat is grown under zero-tillage conditions following a pure chemical fallow (3rd type above) it performs best (about 1.6t/ha). A three-year CGS initiative on-farm trial of zero-tillage technology (including crop rotation) has provided first year results with yields 55 percent above conventional farming control area (1.4 t/ha as against 0.9 t/ha). The same institute is experiencing very interesting results by including Sudan Grass in the crop rotation. Sowing occurs late May and the crop is cut beginning August when plants reach a height of about 1.2 meters. This enables a strong enduring stubble 40-50 cm high while fodder mass can be sold green or for silage making. This trial should be repeated elsewhere as it appears to be a promising and low-cost stubble management technique to improve snow trapping.

[23] The 'Introduction of New Technologies and Extension' window of the ACP-CGS would conveniently host such initiatives.