Development, participatory extension and adoption of zero tillage – the case of Syria and Iraq 2005-14

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Abstract
This paper presents experiences in an Australian-funded project which aimed to improve crop productivity, profitability and sustainability through the development and promotion of zero tillage (ZT) cropping in Iraq and Syria. As a result of the project, the area of ZT crops in Syria increased from a zero base in 2006 to 30,000 ha grown by more than 500 farmers in 2011-12. In Iraq, there was about 15,000 ha of ZT crops grown by 100 farmers in 2013-14, also from a zero base in 2006. Whilst this is only a small percentage – around 1.8% for Syria and 0.9% for Iraq - of the wheat area grown, it is considered a good foundation for on-going uptake of ZT. The success of the project can be attributed to five critical strategies: 1) recognition of problems and the need for change, 2) identification of better technology, 3) research for local verification and adaptation of ZT, 4) addressing constraints through local fabrication of ZT seeders, and 5) participatory extension to enhance ZT awareness and experience and promote ZT adoption. For the vast majority of farmers taking up the technology, ZT and early sowing resulted in cost savings, increases in grain yield, reduced environmental degradation, and improved soil quality. In surveys of Syrian wheat farmers who had adopted ZT and early sowing, yields were increased by 465 kg/ha and net incomes were boosted by $US 194/ha on average. If 80% of wheat farmers growing the ≈1.7 million hectare wheat crop in Syria used ZT this would produce an extra 630,000 tonnes of wheat worth about $US 250 million per year. Iraq has similar wheat areas to Syria and benefits from ZT might be higher due to higher wheat prices. Other crops would also benefit from ZT. Importantly for the region, the technology decreases the risk of crop failure under dry conditions and reduces the negative effects of climate change. The project is a successful example of adapting and applying Australian knowledge and skills for the benefit of partner countries that have similar agro-ecological conditions as Australia.

Key Words
Zero tillage, participatory extension, early sowing, low seed rates, conservation agriculture, Iraq, Syria

Introduction

Dryland cropping in Syria and Iraq and the wider West Asia and North Africa (WANA) region is characterized by grazing, burning or harvesting of crop residues, multiple cultivations, late sowing, and high seed rates which results in high costs, limited yields, and soil erosion and degradation (Cooper *et al.* 1987, Pala *et al.* 2000, Moeller *et al.* 2014, Loss *et al.* 2015). In the dryland areas of the Mediterranean region where low and variable rainfall (250-350mm) mostly falls between October and April, cereal and legume yields are often low. In wheat, which is the major crop in the region, grain yields are commonly less than 1t/ha (Moeller *et al.* 2014, Loss *et al.* 2015), well below water-limited or attainable yields of around 4.2-6.4 t/ha (Sadras and Angus 2012). In contrast, many farmers in similar areas of Australia now approach attainable yields through the use of improved crop varieties and better agronomy (Anderson *et al.* 2005, Sadras and Angus 2006, Anderson 2010, Passioura and Angus 2010, Kirkegaard *et al.* 2014, Richards *et al.* 2014).

In Australia, a key component of better crop management has been the use of zero tillage (ZT) to sow crops early with no prior cultivation, low soil disturbance and retention of stubble. Over the last 30 years, ZT has been adopted by about 80-90% of Australian farmers (Llewellyn *et al.* 2012), who have been attracted by the better flexibility, productivity, profitability and sustainability of the ZT system. In WANA over this time, ZT has been little known, researched or adopted. This paper presents some experiences in an Australian-funded project (2005-14) which aimed to improve crop productivity, profitability and sustainability through the development and promotion of ZT cropping in Iraq and Syria. Project partners were the International Center for Agricultural Research in Dry Areas (ICARDA) in Syria; the Ministry of Agriculture (Directorate of Agriculture, State Board for Agricultural Research) and the University of Mosul in Iraq; and the Universities of Adelaide and Western Australia and the Western Australian Department of Agriculture in Australia.

During the life of the project, ICARDA and Australian collaborators were unable to visit Iraq due to security concerns and all implementation within Iraq was undertaken by Iraqi collaborators. ICARDA was a meeting, testing and training ground for project collaborators, where work programs were planned, progress was reported, technologies were tested and adapted, and training courses were undertaken. Although not formal partners in the project, many Syrian institutions, machinery manufacturers and farmers interested in this "new" ZT technology became involved in and made a great contribution to developing, testing and promoting ZT systems and encouraging their wide adoption in Syria.

The success of the project can be attributed to five critical strategies: 1) recognition of problems and the need for change, 2) availability of better technology, 3) research for local verification and adaptation of ZT, 4) addressing constraints through local fabrication of effective, affordable ZT seeders, and 5) participatory extension to enhance ZT awareness and experience and promote ZT adoption.

Recognition of problems and the need for change

The prevailing conventional cropping system in the dryland areas of WANA has been characterized by heavy grazing or burning of crop stubbles and residues, multiple cultivations before sowing, late sowing (Dec-Jan), high seeding rates (with disc plow seeding in some areas), and little diversity in cereal-fallow or cereal-cereal rotations (Cooper *et al.* 1987, Pala *et al.* 2000, Moeller *et al.* 2014, Loss *et al.* 2015). The consequences of such a system are poor storage of soil moisture, high costs of land preparation, delayed sowing, low grain yields and profitability, water and wind erosion, soil degradation, and air pollution from burning stubbles and dust. Adding to these problems are declining rainfall and more variable weather due to climate change. At the time the project started in early 2005, Iraqi farmers and scientists recognized the need for a more productive, profitable and sustainable system, especially in light of increasing costs and reduced availability of diesel fuel and the degradation of soils.

Availability of better technology

ZT cropping with minimal soil disturbance, early sowing and retention of some crop residues was seen as a technology with great potential to increase the productivity, profitability and sustainability of cropping systems in WANA, especially given its success in Australia (Llewellyn *et al.* 2012), where the climate, soils and crops have many similarities (Loss *et al.* 2015), and in many other countries. ZT cropping can provide benefits related to the crop (early sowing, higher yield potential, and savings in time, machinery maintenance and fuel), the soil (better soil structure, higher organic matter, increased porosity, better soil-water dynamics, increased nutrient recycling, and improved trafficability), and the environment (less pollution, less erosion, and increased C sequestration). Although widely adopted around the world, ZT, strangely, was little known and unused by farmers in Iraq or Syria in 2005.

The ZT system developed and promoted by the project was based around eliminating pre-sowing cultivation and sowing seed (and fertilizer if applied) through surface residues from the previous crop into narrow (≈10-20mm) slits/furrows opened in the soil by the narrow points/tines of a ZT seeder. The conventional tillage (CT) system, used by most farmers in Syria and Iraq, involved one to three or more cultivations with mouldboard, disc or chisel plows and seeding into bare cultivated soil with a drill or disc plow seeder (Pala *et al.* 2000, Moeller *et al.* 2014, Loss *et al.* 2015, Piggin *et al.* 2015).

Research for local verification and adaptation

A field research program commenced in Syria in 2005-06 at ICARDA's station, just south of Aleppo, to test and adapt the ZT system, and compare its performance with CT systems (Piggin *et al.* 2011, Sommer *et al.* 2014, Piggin *et al.* 2015). Over 10 years, a series of experiments showed in general that:

- ZT was more productive, sustainable and profitable than CT
- all crops (wheat, barley, oats, chickpea, lentil, faba beans, field peas) performed well under ZT
- there was no need for special ZT varieties; the best ones under CT were also the best under ZT
- early sowing facilitated by ZT was more productive than late sowing
- stubble retention had little effect on crop performance, especially in early years
- low seed rates (50-100kg/ha) were more productive than high seed rates (200-300kg/ha)
- crops little grown in the Middle East (field peas, oats) performed well under ZT and can provide diversity in rotations.

Seeing and/or hearing about these trials gave researchers and farmers an interest and confidence to consider and incorporate some of the findings in demonstrations and broad-acre crops on-farm in both Syria and Iraq.

To guide users, a list of possible management options to maximize production, profitability and sustainability was developed from these and other research findings, with those considered most important in changing from CT to ZT systems highlighted in bold:

- **stop plowing**
- **don't burn stubble** – keep as much as possible on the soil surface
- **use ZT seeders** for all crops
- **if weeds are present before sowing** kill them with glyphosate
- **plant early** (late October/early November)
- use good quality seed of the best adapted varieties
- **reduce seeding rates** to 50-100kg/ha for cereals and 100-150kg/ha for pulses
- sow at the optimum depth (4-6cm)
- use the best available fertility & weed/disease/pest management
- include non-cereals in rotations if possible
- graze crop residues and stubble if needed - this doesn't cancel ZT benefits.

The project did not promote these options in any sort of fixed "package" but rather suggested farmers focus with flexibility on those components highlighted above in bold, which are important in changing from CT to ZT systems and likely to provide the greatest immediate benefits through reduced costs (fuel, labor and seed) and increased yields. Other (non-bolded) components were seen as part of good crop management in any tillage system, to be considered and used as and when required. It was recognized that some components may not be appropriate in certain situations. For example, in Syria and Iraq, and elsewhere in WANA, stubble retention is difficult because crop residues are highly valued as a stockfeed and there are few fences to control livestock, so crop residues are generally heavily utilized. Also, crop rotation is limited because wheat is the most reliable and profitable crop (partially due to government subsidies), which discourages inclusion of legumes in rotations. A flexible approach is also used in Australia, where farmers are pragmatic rather than prescriptive about the use of "ideal" conservation agriculture (CA) components as they are now commonly promoted (ZT with no soil disturbance, full stubble retention and >3 species in the rotation), and many farmers continue some strategic tillage, intensive cereal systems dominate, and partial removal of crop residues as hay or by grazing livestock is commonplace, to optimize both economic and environmental outcomes (Kirkegaard *et al.* 2014).

Simple economics suggested there could be attractive returns and savings with eliminating unnecessary cultivation, adopting ZT and early sowing, and reducing seeding rates to 50kg/ha (Table 1).

Table 1. Possible economic returns/savings in Syria with wheat grown using ZT, early sowing and a low seed rate compared to CT, late sowing and high seed rate.

Operation	Change	Return or saving /ha ($US)
Use ZT and early sowing	+ 500 kg/ha yield	$200
Stop plowing	2 → 0 times	$ 50
Reduce seeding rate	300 → 50 kg/ha	$100
Reduce seeding rate	+ 1,000 kg/ha yield	$400
Total		$750

Local fabrication of ZT seeders

A major constraint to the adoption of ZT was the lack of effective, affordable, locally-available ZT seeders. Imported ZT seeders were too large, complex and expensive for small-scale farmers, and accessing parts and maintenance locally would have been difficult. In response, the project discussed and demonstrated ZT seeding technologies with local seeder manufacturers in Syria in 2007-08 and, guided by Australian experience and engineering expertise, worked with three workshops around Aleppo to design and fabricate various ZT seeder prototypes. The first ZT seeders were 2.3m wide, with three-point-linkage mountings suitable for small tractors (60-100hp) common in the region. They had narrow points/openers (≈10-20mm), widely-spaced tines which were spring-loaded for rocky areas, and separate seed and fertilizer delivery capacity.

Following evaluation and feedback from farmers, 4m wide trailed and three-point-linkage ZT seeders with wider tine spacing for better stubble flow were also fabricated for larger tractors and more extensive cropping areas in eastern Syria and Iraq. These all worked effectively at ICARDA and in farmer fields. In an experiment with early (mid-Nov) and late (mid-Dec) sowings in 2008-09, crop establishment and yields for wheat, barley, lentil or chickpea were similar when sown with imported ZT seeders from India and Germany and the three locally-made ZT seeders. With this early success, other interested seeder manufacturers were assisted by the project to begin fabricating and marketing ZT seeders.

By 2011-12, after many improvements in materials, design and construction, there were seven local workshops making effective ZT seeders in Syria. Prices for these locally-made ZT seeders were around

US$1,500 for 2.3m wide and $4,500 for 4m wide models. These were affordable for farmers and by 2011-12, 92 ZT seeders had been fabricated, of which 26 were purchased by Syrian farmers and 28 were sent to Iraq for evaluation and use in demonstration and extension programs (Table 2). Local production has greatly increased farmer access to ZT seeders.

Table 2. Number of ZT seeders manufactured in Syria 2008-09 to 2011-12.

Purchaser	2008-09	2009-10	2010-11	2011-12	Total
ICARDA	3	6	3		12
Syrian Govt.		2	2	1	5
Syrian NGOs			**1**	**5**	**6**
Syrian farmers		4	**14**	**8**	**26**
Iraq projects	4		**14**	**10**	**28**
Other countries		1	10	4	15
Totals	7	13	44	28	92

The pathway to local manufacture of ZT seeders was different in Iraq, due to the lack of operational seeder manufacturers and difficulties with security and accessing required construction materials in rural areas. After Syrian-made ZT seeders were sent to Iraq in 2008-09 and used in demonstrations and farmer fields, some innovative Iraqi farmers developed very effective ZT conversion kits (basically narrow tines and openers spaced more widely on the seeder frame) for the widely available John Shearer-type conventional seeders, which greatly increased local access to ZT seeders for demonstrations and farmers. With time, capacity for local fabrication has been developed and two manufacturers in Mosul are making effective and affordable ZT seeders, with 9 produced in 2013-14. Unfortunately, local ZT seeder fabrication has been greatly restricted by the post-2010 civil unrest in both Syria and Iraq and few are being manufactured or purchased.

Participatory extension – enhancing ZT awareness, knowledge and experience

In Syria, researchers, extension specialists, farmers and others with an interest in ZT undertook study tours to inspect and discuss research at ICARDA, visit local ZT seeder manufacturing workshops, and meet farmers involved in early testing of ZT on their own farms. These tours greatly increased awareness and knowledge of ZT cropping and ZT seeders. Some 400-600 people visited ICARDA in each of the three years from 2008-09 to 2010-11 (Table 3) which encouraged exchange of ideas and experiences with ZT between ICARDA and Iraqi/Syrian researchers, extension officers, seeder manufacturers, and farmers.

Table 3. Numbers of visitors inspecting ZT research trials at ICARDA, local seeder manufacturers and pioneer farmers.

Visitors	2008-09	2009-10	2010-11	Total
Iraqi/Syrian project scientists and farmers	100	100	80	280
Others	500	300	300	1,100
Total	600	400	380	1,380

Practical experience of growing crops with ZT was enhanced by establishing participatory ZT working groups in Syria to facilitate farmer testing of ZT on their own farms. The working groups involved ICARDA, research and extension scientists from the Ministry of Agriculture, seeder manufacturers, private industries, NGOs and farmers. The program expanded from seven to fourteen groups between 2009-10 and 2011-12. In this program, general arrangements for the ZT working groups were:

- a group was established for each location and a leader selected

- a local ZT seeder was assigned to the group
- farmers registered their interest to use the ZT seeder with the group leader
- the ZT seeder was made available to farmers without charge or payment
- the farmer was responsible for all inputs (tractor, seed, fertilizer) and sowing the crop
- the farmer was responsible for the transfer of the ZT seeder in good condition to the next farmer
- ICARDA supported some long-distance transport and major maintenance when necessary
- ICARDA and Syrian institutions provided technical and other support for the leader and group
- the group arranged farm walks, field inspections, and field days
- farmers recorded yields of their ZT crop and nearby CT fields.

Most Syrian farmers tested and adopted ZT and early sowing, and many used reduced seed rates. Very few retained significant amounts of stubble, or changed their cereal-dominated rotations. Despite this, farmers generally found yields were better with ZT and early sowing than with CT. Information collected from the farmers over the three years from 2008-09 to 2010-11 (Loss *et al.* 2014) showed that the average grain yield increases with ZT compared to CT were 0.26 t/ha (15%) for barley (number of fields = 278), 0.33 t/ha (19%) for wheat (n = 264), and 0.23 t/ha (21%) for lentil (n = 88). Along with these yield increases, significant savings in time, machinery costs and fuel were reported. These on-farm yields increases were similar to those recorded in a long-term trial at ICARDA, where the average (2008-09 to 2011-12) grain yield increases of ZT with early sowing compared to CT with late sowing were a significant 0.33 t/ha (18%) for wheat, 0.13 t/ha (20%) for chickpea and 0.14 t/ha (15%) for lentil, and a non-significant 0.30 t/ha (12%) for barley (Piggin *et al.* 2015).

The working groups held many field days and farm walks in farmer fields to inspect and discuss ZT crops and seeders. For example, in 2009-10, there were three major ZT field days on-farm in northern Syria, each attended by 300-400 people. These Syrian field days were also linked to training at ICARDA for Iraqi/Syrian scientists on participatory extension and for Iraqi/Syrian farmers on a ZT study tour. The opportunity to see ZT crops and seeders, and hear how farmers had adapted the technology to their farming operations, had a great impact on field day participants and promoted wide interest and uptake of ZT. Unfortunately, in Syria, unrest and insecurity curtailed the participatory extension program and further field days after mid-2011.

In Iraq, in a necessarily different approach to participatory development and extension, ZT technology was tested, developed and promoted through large-scale, long-term demonstrations in farmer fields comparing ZT and CT systems, planting times and seed rates. Crops were sown with Syrian-supplied or Iraqi farmer-converted ZT seeders. The program started in 2005-06 with 12 demonstration locations and additional locations were added after 2008-09 as farmer interest spread and more local seeders became available. By 2012-13, the program had expanded to 37 districts in Ninevah and 14 in the surrounding Governorates of Anbar (5), Salahaldin (4) and Kirkuk (5). Farmers were actively involved together with extension and research collaborators in the management of these demonstrations. Each year, there were regular inspections and field days, often with 40-50 scientists and farmers attending. The participatory extension program encouraged great interest in ZT amongst Iraqi farmers and, as in Syria, those wanting to try ZT on their own farms were able to get access to a ZT seeder from the project or from another farmer. In Iraq, unrest and insecurity curtailed demonstrations and further field days after 2013-14.

Adoption

During 2005 to 2012 there was remarkable progress in the development, promotion and adoption of ZT in Syria and Iraq (Figure 1). In Syria, from a zero base in 2005-06, the area of ZT crops increased to 30,000 ha grown by 500+ farmers by 2011-12 (the last reliable figures available). Some 70-80% of this area was true adoption, where farmers owned, rented or borrowed a ZT seeder independent of the working groups. In Iraq, there was some 15,000ha of ZT crops grown by about 100 farmers in 2013-14. Whilst these areas represented only a small percentage of cropped land (1.8% and 0.9% of the 1.7 million hectares of wheat in Syria and Iraq respectively), it is considered that they form a sound foundation of experience for self-sustaining expansion of ZT.

As has been the case in many parts of the world, many Syrian and Iraqi farmers struggled to accept that crops could be grown without cultivation. The participatory ZT working groups were an excellent way to raise awareness and experience, and give farmers the confidence and opportunity to test and adopt ZT. There was much farmer to farmer learning and local ZT champions emerged from many groups. Local manufacturing of ZT seeders was critical to support expanding adoption, and the links between farmers and seeder manufacturers were very important to encourage user feedback and enable improvements in seeder design and production. It was no coincidence that ZT adoption began to accelerate after 2008-09 (Figure 1) when ZT seeders became more widely available (see Table 2) to support a major campaign of participatory extension which in turn facilitated farmers gaining experience with establishing and managing ZT crops with early sowing and low seed rates.

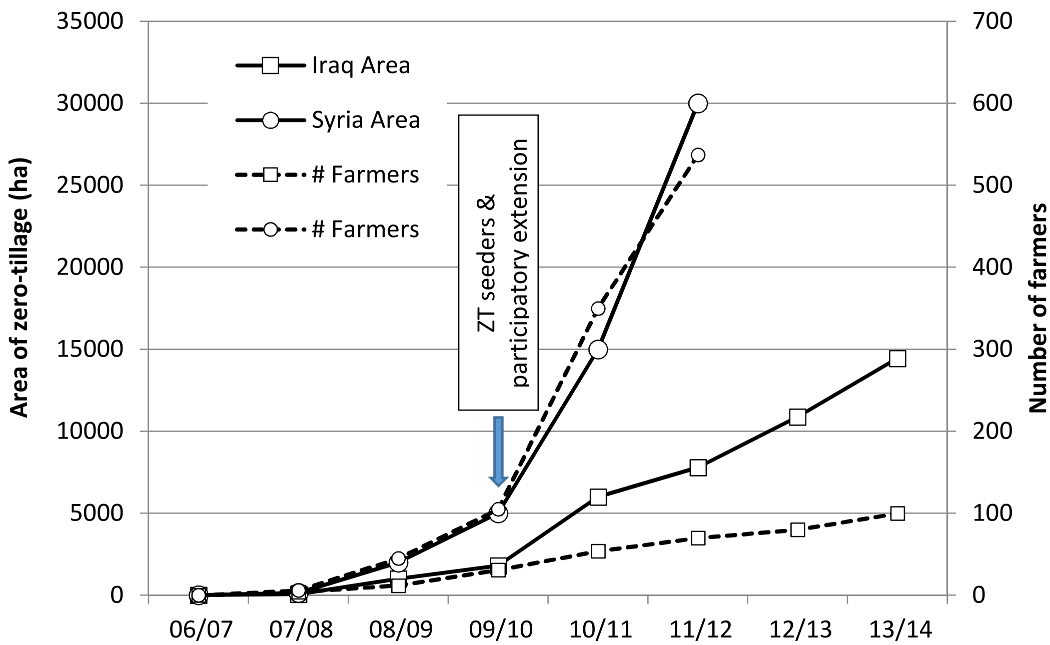

Figure 1. Area under ZT and number of farmers using ZT in Syria and Iraq (2006/14)

This success has been due in no small manner to the ongoing dedicated work to develop and promote ZT by researchers, extension specialists, farmers and manufacturers as civil unrest escalated after 2011-12 in Syria and Iraq. ZT is continuing to be popular amongst farmers because, without plowing, the requirement for increasingly scarce and expensive fuel and the risks to personal safety are both reduced with less time working in fields and transporting cultivation machinery on roads. While the overall cropping area has decreased in the past two or three years in both countries due to the civil unrest, anecdotal evidence suggests the proportion of crop sown using ZT has increased.

Economic impacts

The economic impacts of adopting ZT are potentially large. In a 2011 survey of Syrian wheat farmers who had adopted ZT (often with early sowing and lowered seed rates), on average, grain yields were increased by 465 kg/ha and net incomes by US$ 194/ha (Yigezu *et al.* 2014). In Syria in 2011-12, the total benefit across 30,000 ha was about $5.8 million. If 80% of farmers growing the 1.7 million hectare wheat crop in Syria used ZT (the typical levels of adoption in many parts of Australia), this would produce an extra 630,000 tonnes of wheat worth about $250 million per year at the subsidized price of $400/tonne. Iraq has similar wheat areas to Syria but benefits from ZT might be higher; the subsidized price for wheat was $700/tonne in Iraq in 2011-12 before the unrest broke out. Of course other crops would also benefit from ZT. The development of seeder workshops also provides valuable business opportunities and much needed employment in rural areas. ZT could have a similar major impact on the economic productivity and food security of many WANA countries which have similar Mediterranean environments and cropping systems, reducing reliance on imports to feed their populations.

Conclusions

At the start of the project, farmers and scientists in Syria and Iraq were understandably skeptical about the possibility of growing crops without tillage but had an understanding and concern that their heavily-cultivated, conventional systems were limiting production, degrading soils and polluting the environment with dust and smoke. The research and demonstration programs in both Syria and Iraq, conducted on large plots, were central to verifying, adapting and raising awareness and understanding of ZT systems and identifying some technology options (no plowing, ZT, early sowing, low seed rates, no stubble burning) for farmers to consider, evaluate and adopt on their own farms. There was no promotion of a fixed "package" (e.g., CA); rather, flexibility was emphasized and farmers were free to choose the ZT system components they wished to use. Perhaps the most important initiative was to work with local engineering companies and innovative farmers to develop capacity to fabricate effective and affordable ZT seeders and ZT conversion kits, and provide farmers with ready access to suppliers for seeder purchase, repairs and maintenance and to receive feedback on design and performance. Success of projects promoting ZT systems can be limited if there is reliance on less well-adapted, expensive, imported seeders. The participatory extension program, involving participation in training courses, demonstrations, study tours, field days and farm walks, and providing access to a ZT seeder for interested farmers to test ZT on their own farms, was a key to increasing farmer knowledge, experience, ownership and uptake of ZT systems.

That this logical project approach brought encouraging adoption of ZT – 30,000ha by 500 farmers in Syria by 2011/12 and 15,000ha by 100 farmers in Iraq by 2013/14 – is not surprising because the technology is highly relevant to farmer concerns of low yields and resource degradation, highly compatible with existing mechanized cropping operations, and can increase wheat yields by ≈500 kg/ha and income by ≈$ 200/ha, or more, in farmer fields. Farmer surveys confirmed that project strategies such as facilitating farmer testing of ZT on-farm and participation in field days increased the probability of adoption (Yigezu *et al.* 2015). The project experience is that ZT is not scale-, soil- or crop-specific and, for farmers already growing dryland crops, ZT can be a simple alternative to CT, provided there is access to an owned, borrowed or rented ZT seeder, with adjustments e.g. herbicides, residue handling, disease management rather than major changes required to existing cropping operations. Whether adoption will expand to 80-90% of farmers over the next 20 years, and match that achieved in Australia over the last 30 years (Llewellyn *et al.* 2012), will depend, amongst other things, on the continuation of effective research, development and extension and, importantly, the cessation of unrest and violent conflict in Iraq and Syria.

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