I had the opportunity to visit Dr. Asadi in Iran and was extremely impressed with the efforts he and his colleagues have made. This book offers an excellent example of how new, relevant technologies can be adopted for farmers in new production situations.

Professor Kenet. D. Sayre

Aug 2020.



# **Preface**

# **Kenneth D. Sayre**

The most important challenges facing agriculture production across the world and the farmers who must produce our food is to dramatically increase water productivity in both rainfed and irrigated production systems and to enhance the productivity of soils especially to maintain or increase organic matter/fertility, reduce soil losses through erosion and dramatically reduce pest, disease and weed levels.

 The implementation of the principles of Conservation Agriculture (CA) provides farmers with the tools to address improved water use efficiency, soil productivity and pest control. The three principles of CA include to make dramatic reductions in tillage with the goal to reach as close as possible to zero tillage, to retain adequate levels or crop residues on the soil surface and to economically diversify crop rotations. The technology called permanent raised bed cropping systems that Dr. Asadi and his colleagues are implementing in Iran and that Dr. Asadi clearly explains in this book is a clear demonstration of a CA-based technology that allows farmers to effectively implement the principles of CA in their fields.

The permanent raised bed production system was initially developed in an irrigated production area in the Yaqui Valley of Sonora in Northwest Mexico by scientists at the International Maize and Wheat Improvement Center (CIMMYT) based in Mexico. Irrigation was developed in the Yaqui Valley during the 1950s and initially was based on flood irrigation. In the 1970s Dr. Norman Borlaug and his colleagues working with scientists from Mexican national research organizations introduced furrow irrigation technologies with tillage and by the 1990s more than 90% of the irrigated area in the Yaqui Valley was converted to the much more efficient furrow irrigation system.

During the 1990s CIMMYT scientists initiated the development of the permanent raised bed production system. As this process developed farmers began to adopt the system and CIMMYT began to offer training courses for scientists from countries around the world emphasizing CA-based production systems including permanent raised beds. Dr. Asadi participated in this course and returned to Iran to initiate his work to develop and extend permanent raised bed cropping systems in Iran that he discusses in detail in this book. I had the opportunity to visit him in Iran and was extremely impressed with the efforts he and his colleagues have made. This book offers an excellent example of how new, relevant technologies can be adopted for farmers in new production situations.

**Permanent raised bed cropping system**

**By: Mohammad Esmaeil Asadi**

**Senior Research Scientist of Agricultural Water Mangement and Conservation Agriculture Systems, Gorgan, Iran.**

**E-mail:** [**iwc977127@yahoo.com**](mailto:iwc977127@yahoo.com)**.**

Of a total global land area of 13,000 Mha, arable land and permanent crops account for by 12%, permanent meadows and pastures for 26%, forests for 30% whereas 32% of this land is unsuitable for agriculture. Analysis that accounts for suitability of remaining land for cropping and alternative land uses concludes that expansion of cropping land to 2050 is likely to be small. Globally, 15% of arable land is irrigated and currently accounts for 42% of all crop production; 7100 km3 of water are consumed annually to produce food globally whereas feeding the world population of around 9 billion by 2050 would require an additional 2100 km3 year (the global water demand of agriculture due to irrigational needs).

Agriculture is the sector with by far the largest consumer of water makes use of 70% of all water withdrawn from groundwater and surface water resources, three times more than 50 years ago. Especially in the densely populated regions of South East Asia, the main factor for increasing yields were huge investments in additional irrigation systems between the 1960s and 1980s. Considering Asian and African countries, the water systems of the Near East and North Africa Region (NENA) are considered ‘fragile’ and ‘unsustainable’ with the current management approach. In those countries, irrigated agriculture is the major water user, withdrawing about 85 percent of all renewable water resources, imposing heavily on rivers and groundwater. It is disputed where the further expansion of irrigation, as well as additional water withdrawals from rivers and groundwater, will be possible in the future, how this can take place and whether it makes sense. Agriculture already competes with peoples’ everyday use and environmental needs, particularly in the areas where irrigation is essential, thus threatening to literally dry up ecosystems. In addition, in the coming years, climate change will bring about enormous and partly unpredictable changes in the availability of water. Recent evidence shows that groundwater supplies are diminishing, with an estimated 20% of the world’s aquifers being over-exploited, some massively so. Globally, total freshwater withdrawals (both surface water and groundwater) are believed to have increased by about 1% per year since the late 1980s, almost exclusively in developing countries. Annual freshwater withdrawals appear to have stabilized or even declined in the majority of the world’s most highly developed countries, suggesting improvements in efficiency, crop water productivity (CWP) and increasing reliance on the importation of water intensive goods, including food.

Without improved efficiencies and CWP, agricultural water consumption is expected to increase by about 20% globally by 2050. The solution to these problems is apparently simple: less water must be consumed, treated waste water should be reused, and whatever water is available should be used as productively as possible. CWP can be defined in two ways including bio-physical water productivity (kg of produce per unit of water consumed; kg.m-3) and economic water productivity (value of produce per unit of water consumed; USD per m3 of water).

For these reasons, permanent raised bed (PRB) cropping system that would increase CWP and reduce the ecological impact of cropping systems in well-watered environments was introduced. Permanent bed systems are forms of irrigated conservation agriculture (CA), which would conserve both natural resources, water and soil. The beginnings of PRB system, technique of planting on narrow raised beds with irrigation water conﬁned to furrows between the beds, arose by farmers in the Yaqui Valley in northwestern Mexico in 1970s. In PRB method cropping systems has been changed from the previous practice of planting most crops (especially wheat) on the ﬂat with ﬂood/basin irrigation to the establishment of all their crops (including wheat) on no till raised beds using furrow irrigation. Wheat, soybean, corn, cotton, canola and other crops are planted in rows on top of the beds (one to six rows depend on bed width), which normally measure 70–100 cm wide between bed centers. Depending on tractor wheel widths and bed planter configurations, the gap (furrows) can be between 40 and 60 cm wide, that is from the last row of plants on one bed to the first row on the adjacent bed, and cumulatively can appear to occupy half of the land area. The gaps between the beds supply the irrigation water and drainage, the access for humans for hand operations such as weeding, and the tracks for wheels of machinery for weeding, fertilizer applications and harvesting. In the PRB the beds are retained over many seasons for successive wheat crops and rotation crops (soybean, corn, canola, safflower and so on). Machinery wheels do not go on the beds but in the furrow or gaps (traffic control).

The new system could be useful in extensive areas of the developing world including Iran. In South Asia alone, irrigated wheat is planted on nearly 25 million hectares. More than 13 million hectares are planted in China and substantial areas are also grown in countries such as Turkey, Afghanistan, Iran, Egypt, Sudan, Ethiopia, Zimbabwe, Nigeria, Mexico, and Chile.

We are confident that it can play an important role in rise of CWP. The role bed-planting may play in areas like Iran where water is a limiting factor has yet to be determined, but applications of PRB, residue retention, and tied ridges may increase its feasibility. PRB planting not only reduces irrigation water use by 12–60% and improves drainage but also reduces CH4 emission. Most of the water savings were caused by reduced percolation and evaporation losses. There are several reports of reduced irrigation amounts or time by up to 30–40%, with similar or higher yields for wheat on raised beds compared to conventional tilled wheat. In the rice–wheat systems of India, irrigation water saving ranged from 18 to 50% with adoption of bed planting system. In addition, there were savings of about 25% nitrogen and 25–50% seed, indicating much higher nitrogen and WUEs in bed planting compared to conventional flat plating of wheat. Crops on beds with residue retained on surface are less prone to lodging and more tolerant to water stress, thereby making it more adaptable to unfavorable climate.

The great advantages for PRB are the tremendously enhanced field access, which facilitates controlling weed and other pests, handling nutrients, reducing tillage, and managing crop residues. Rapid drainage of irrigation water from the bed surface avoids the negative effects of ponding and associated waterlogging. It avoids deoxygenating of the upper rooting zone for extended periods, and allows rapid access to the bed surface for mechanical or hand activities after irrigation. Because of easy access by machinery with no compacting of the beds, nitrogen can be applied by banding. Furthermore crops that planted on beds can capture solar radiation better than flat conditions. This is of particular importance in short season crops and in hotter environments. In this environment the main consideration is the ability of the cultivar to capture the solar radiation falling in the gap between the beds, and that the common gap of 44 cm could be compensated for in most cultivars. Crop residues can be left on beds for stabilization. No till systems can be used more profitably on beds. Overall economic CWP is increased with the bed system because inputs are reduced (herbicides, insecticides, fertilizers, water) without a major penalty in yield. A most significant benefit in multiple cropping systems such as a rice-wheat rotation is that change time between crops is short. Theoretically, wheat can be planted the day after the preceding rice crop is harvested using minimum or no till on beds. This technique enhances CWP in irrigated conditions thanks to minimum soil disturbance (no tillage), soil cover and appropriate crop association. The adoption of this planting system as CA and its effects on the improvement on soil attributes has the potential to reduce substantially the degree of soil erosion, as well as to improve the farmer’s income by increasing grain yields and reducing production costs.

In recent years PRB cropping systems have been adopted in a wide range of irrigated and dry-land farming systems. Early work on PRB began in Mexico, initiated by CIMMYT (International Maize and Wheat Improvement Center).

This book was written to help raise awareness of the need to save agricultural water use. The author wishes to provide Iranian farmers, experts, academics, students, professionals, researchers, educationalists, activists, service providers, decision-makers in the agricultural organizations, extension staff of development agencies, and technical assistance agencies the opportunity to learn and contribute to promote this new approach across the country for improvement of soil and water productivities and safeguarding water supplies. I am sure this is going to be a very valuable book.

**M. E. Asadi**

**Sep 2020**

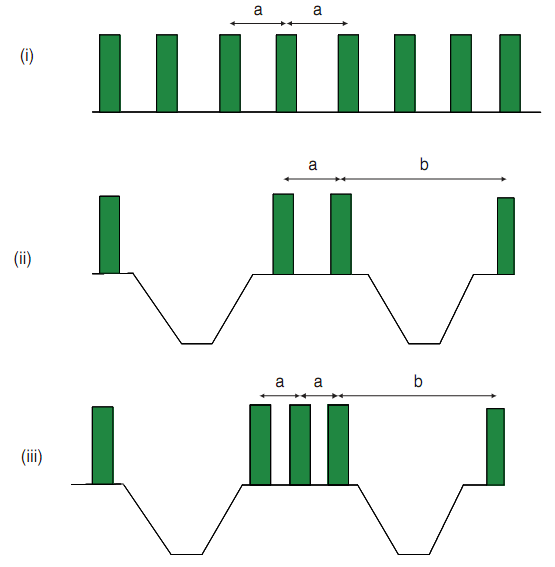
**References**

1. Ahmad, R. N., and Mahmood, N. 2005. Impact of raised bed technology on water productivity and lodging of wheat. Pakistan Journal of Water Resources, Vol.9(2): 6-15.
2. Aquino, P. 1998. The adoption of bed planting of wheat in the Yaqui Valley, Sonora, Mexico. Wheat Special Report No. 17a. Mexico, DF: CIMMYT.
3. Borrell, A., Garside. A. 2005. Early work on permanent raised beds in tropical and subtropical Australia focusing on the development of a rice-based cropping system. ACIAR Proceedings.121: 120-128.
4. Bouman, B.A.M. 2007. A conceptual framework for the improvement of crop water productivity at different spatial scales. Agricultural Systems 93: 43-60.
5. Crews, T.E., and Gliessman,.S.R. 1991. Raised field agriculture in Tlaxcala,Mexico: An ecosystem perspective on maintenance of soil fertility. Am. J,Alternative Agric. 6: 9–16.
6. Das, T. K., Sharawat, Y.S., Bhattacharyya, R., Sudhishri, S., Bandyopadhyay, K.K., Sharma, A.R., and Jat, M.L., 2018. Conservation agriculture effects on crop and water productivity, profitability and soil organic carbon accumulation under a maize-wheat cropping system in the North-Western Indo-Gangetic plains. Field Crops Research, 215: 222-231.
7. FAO. 2011. The state of the world’s land and water resources for food and agriculture (SOLAW) – Managing systems at risk. (Food and Agriculture Organization of the United Nations, Rome and Earthscan, London, 2011).
8. Fischer, R.A., Sayre, K., and Ortiz Monasterio, I. 2005. The effect of raised bed planting on irrigated wheat yield as inﬂuenced by variety and row spacing. Proceedings of a workshop held in Grifﬁth, NSW, Australia, 1–3 March 2005.
9. Hassan, I., Hussain, Z., and Akbar. G. 2005. Effect of permanent raised beds on water productivity for irrigated maize–wheat cropping system. ACIAR Proceedings. 121: 59-65.
10. Hobbs, P. R. and Morris, M. L. 1996. Meeting South Asia’s future food requirements from Rice-Wheat Cropping Systems: Priority Issues Facing Researchers in the Post Green Revolution Era. NRG Paper 96-01. Mexico, DF.:CIMMYT.
11. Kassam, A. 2018. Reversing and mitigating agricultural land degradation worldwide: can conservation agriculture contribute to implementation ofland degradation neutrality? <http://www.act-africa.org/news.php?com=6&item=437>.
12. Kukal, S. S., Humphreys, E., Singh, Y., Timsina, J., and Thaman, S. 2005. Performance of raised beds in rice–wheat systemsof northwestern India. ACIAR Proceedings. 121:26-40.
13. Limon-Ortega, A. 2011. Planting system on permanent beds a conservation agriculture alternative for crop production in the Mexican Plateau. In Godone, D and Stanchi, S. (Eds.), Soil erosion issues in agriculture. InTech Press. Croatia, pp. 183-206.
14. Limon-Ortega, A and Sayre, K. 2012. Rainfall as a limiting factor for wheat grain yield in permanent raised-beds. Agronomy Journal. 104 (4):1171-1175.
15. Lumpkin, T. A., and Sayre, K. 2009. Enhancing resource productivity and efficiency through conservation agriculture. *Lead papers, 4th world congress on conservation agriculture* (pp. 3-9). 4-7 February 2009, New Delhi, India.
16. Majeed, A., Muhmood, A., Niaz, A., Javid, S., Ahmad, Z.H., Hussain Shah, S.S., Hussain, A. 2015. Bed panting of wheat (Tricticum aestivum L.) improves nitrogen use efficiency and grain yield compared to flat planting. The Crop Journal. 3:118-124.
17. Malik, A., Shakir, A.S., Latif, M, and Ajmal, M. 2018. Performance evaluation of the raised-bed planting and potential in improving sugar beet yield and water use efficiency in Pakistan. Sugar Tech 20, 540–551.
18. Naresh1, R.K., Singh, B., Singh, S.P., Singh, P.K., Arvind Kumar, and Amit Kumar. 2012. Furrow irrigated raised bed (FIRB) planting technique for diversification of rice-wheat system for western IGP region. Int. J. Life Sc. Bt & Pharm. Res. Vol. 1 (3).pp.134-141.
19. Prashant S., Raj Khare, Y., and Pahalwan, D.K. 2018. Performance of Chickpea under raised bed planting in Vertisols in central India. International Journal of Current Microbiology and Applied Sciences, 7(3): 810-812.
20. Ram, H., Singh, Y., Timsina, J., Humphreys, E., Dhillon, S.S., Kumar, K., and Kler, D.S. 2005. Performance of upland crops on raised beds in northwestern India. ACIAR Proceedings. 121:41-58
21. Rockström, J., Falkenmark, M., Lannerstad, M. & Karlberg, L. 2012. The planetary water drama: dual task of feeding humanity and curbing climate change. Geophysical Research Letters 39, L15401-L15401, doi: 10.1029/2012gl051688.
22. Sumberg, J. 2012. Mind the (yield) gap(s). Food Security 4, 509-518, doi: 10.1007/ s12571-012-0213-0.
23. Sayre, K. D., and Moreno Ramos, O. H. 1997. Applications of raised bed planting systems to wheat. Wheat Program Special Rep. 31, CIMMYT, Mexico.
24. Sayre, K., Limon, K., and Govaerts, B. 2005. Experiences with permanent bed planting systems CIMMYT, Mexico. ACIAR Proceedings No. 121:12-25.
25. Sayre, K. D, Hobbs, P.R. 2004. The raised-bed system of cultivation for irrigated production conditions. In: Lal R, Hobbs P. R, Uphoff N, Hansen D. O (eds) Sustainable agriculture and the international rice-wheat system. Ohio State University, Columbus, pp 337–355.
26. Sharma, P., Dupare, B.U., and Khandekar, N. Economic Impact Assessment of Broad-Bed Furrow Seed Drill for Soybean. 2020. Agricultural Research 9(3), 392–399. https://doi.org/10.1007/s40003-019-00444-4
27. Singh, B., Naresh, R. K., Singh, K. V., Kumar, A., Bansal, S., and Gupta, R.K. 2010. Influence of permanent raised bed planting and residue management on sustainability of vegetable based farming system in western Indo Gangetic Plains. Annals of Horticulture, Vol. 3 (2). pp. 129- 140.
28. Soomro, A., Nauman, M., Soomro,S. A., Tagar, A.A., Soomro. S.A., Buriro., M. Gandahi, A.W., and Memon, A.H. 2017. Evaluation of raised-bed and conventional irrigation systems for yield and water productivity of wheat crop. Journal of Basic & Applied Sciences.13: 143-149.
29. Tewabe, D., Abebe, A., Enyew, A., and Tsige, A. 2020. Determination of bed width on raised bed irrigation technique of wheat at Koga and Rib Irrigation Projects, North West, Ethiopia. Cogent Food & Agriculture, 6:1, 1712767.
30. Zhongming, M., Liqin, Z., and Fahong, W. 2005. Raised bed planting system for irrigated spring wheat in the Hexi Corridor. ACIAR Proceedings. 121: 105-111.
31. Zwart, S. J., and W. G. M. Bastiaanssen. 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. Agric. Water Manage. 69:115-133.

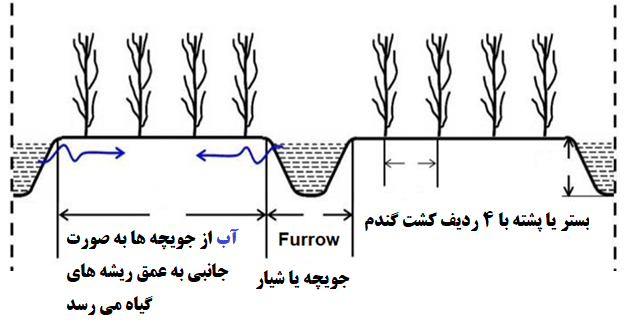
**Photos**

****

**شکل 2-1- استفاده از گاوآهن برگرداندار و خاک‌ورزی شدید برای تهیه زمین جهت کشت گندم در استان سیستان و بلوچستان. آبان 1395.**



**شکل 2-11- عرض بستر بسته به نوع خاک، نوع کشت و ماشین‌های کاشت موجود می‌تواند از 25 تا 200 سانتیمتر متفاوت باشد. شکل (i) کشت مسطح فاصله بین ردیف‌های کشت a سانتیمتر را نشان می‌دهد که با روش غرقابی آبیاری می‌شود. شکل (ii) بستر با دو ردیف کشت فواصل بین ردیف‌های کشت a سانتیمتر و b عرض شیار یا فارو را نشان می‌دهد که برای آبیاری روش جویچه‌ای یا فارویی استفاده می‌شود. شکل (iii) سه ردیف کشت روی بستر با فواصل بین ردیف‌ها a سانتیمتر.**

****

**شکل 2-12- شکل شماتیک سامانه کشت روی بستر بلند با 4 ردیف گندم با شیوه آبیاری جویچه‌ای (Furrow Irrigation) که طریقه نشت آب به محدوده ریشه‌ها را نشان می‌دهد.**

****

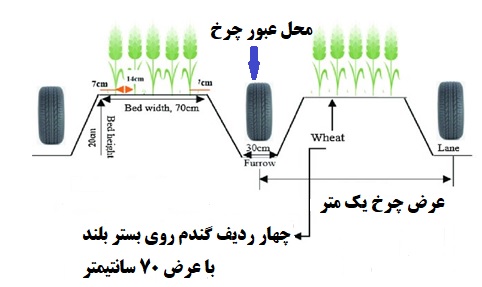
**شکل 2-13- مزرعه گندمی که در پاییز 94 در منطقه کردکوی استان گلستان با استفاده از کودکار بذرکار روی بسترهای بلند کشت گردید و در آن بستر کشت (4 ردیف) و شیار آبیاری مشخص گردیده است.**



**شکل 2-16- مزرعه گندم رقم سیروان با سه ردیف کاشت روی بستر بلند که در تاریخ 8 آذر 1398 به مساحت 7 هکتار با مصرف 200 کیلوگرم بذر در هکتار و در بقایای پنبه در سایت تحقیاتی شرکت فجر سبز و تعاونی پنبه‌کاران شهرستان داراب استان فارس کشت گردیده است. میزان عملکرد 84/8 تن در هکتار. تصویر از جناب مهندس منوچهر دستفال محقق ارجمند کشاورزی حفاظتی استان فارس.**



**شکل 2-23- شکل بالا شیوه کشت گندم به صورت مسطح که حاصل آن غرقاب زمین و ایجاد فرسایش خاک می‌باشد و شکل پایین سامانه بستر بلند بدون آب ماندگی و فرسایش خاک در شهرستان بندرگز واقع در غرب استان گلستان (تصاویر از مدیریت محترم جهاد کشاورزی شهرستان بندرگز آقایان مهندسین محسن مرادیان و محمود رضایی کارشناسان کشاورزی حفاظتی).**



**شکل 2-24- شکل شماتیک سامانه کشت گندم روی بستر بلند با عرض بستر 70 سانتیمتر که در آن محل عبور و مرور چرخهای با عرض یک متر تراکتور در مزرعه که از درون جویچه ها (Furrow) صورت می‌گیرد نشان داده شده است.**



**شکل 2-26- به خاطر حفظ بقایای گیاهی در سامانه کشت بر بستر بلند میزان تبخیر از سطح خاک کاهش یافته و در نتیجه میزان مصرف آب آبیاری کاهش می‌یابد. مزرعه پنبه روی بستر بلند در بقایای گندم در تاریخ 31 تیر 1399 در روستای چهارده شهرستان کردکوی استان گلستان. پنبه این مزرعه در تاریخ 30 خرداد 99 با ماشین کارنده تولید شرکت ماشین برزگر همدان کشت گردید.**



**شکل 2-27- کشت سویا در بقایای گندم روی بستر بلند یک روز بعد از برداشت گندم در تاریخ 26 خرداد 1397 در مزرعه برادران کشیری در شهرستان کردکوی استان گلستان**

****

**شکل 2-28-کشت یونجه رقم قره یونجه بر روی بستر بلند در روستای حاجی بهزاد شهرستان میاندوآب استان آذربایجان غربی که در تاریخ 25 شهریور 1398 کاشته شده است. تصویر از جناب مهندس مهدی زردان مدیرعامل شرکت نوین خدمات دهقان استان آذربایجان غربی. تاریخ عکس 2 شهریور 1399.**

****

**شکل 3-3- آبیاری جویچه‌ای سامانه کشت گندم رقم میهن روی بستر بلند در تاریخ 7 آبان 97 در سایت روستای چوبلوچه شهرستان شاهیندژ آذربایجان غربی که نشان‌دهنده سوار نشدن آب روی بسترهاست.**

****

**شکل 3-4- رشد مناسب چهار ردیف گندم در سایت الگویی سامانه کشت روی بستر بلند روستای گزلان شهرستان میاندوآب استان آذربایجان غربی سال 1398. با تشکر از مجری طرح شرکت نوین خدمات دهقان با مدیریت جناب مهندس مهدی زردان.**

****

**شکل 3-8- سویای برداشت شده از سامانه کشت بستر بلند در پاییز 96 به میزان 3850 کیلوگرم در هکتار. متوسط سویای برداشت شده از مزارع استان 2 هزار کیلوگرم می‌باشد.**



**شکل 3-9- در تاریخ 30 خرداد 99 پنبه رقم مای 344 در بقایای گندم و بر روی هر بستر یک ردیف کشت گردید. این تصویر مزرعه را در تاریخ 9 شهریور 1399 در مرحله رشد زایشی نشان می‌دهد.**