Global Assessment of Redesigned Sustainable Intensification of Agriculture

Supplementary Information

We developed a typology of seven redesign types according to starting intervention: (i) integrated pest management, (ii) conservation agriculture, (iii) integrated crop and biodiversity, (iv) pasture and forage, (v) trees in agricultural systems, (vi) irrigation water management and (vii) intensive small and patch systems. Summary details of each are presented here with examples of illustrative sub-types. The supplementary table contains details of all 47 initiatives included in the global assessment (Table S1).

Type 1. Integrated Pest Management

The most significant design innovation for IPM has been the deployment of Farmer Field Schools (FFS) (1). The aims are education, co-learning and experiential learning so that farmers' innovative expertise is improved. FFS are not only an extension method but also increase knowledge of agroecology, problem-solving skills, group building and political strength. FFS have now been used in 90 countries (2-3), with some 19M farmer graduates, 20,000 of whom are running FFS for other farmers as expert trainers. A synthesis of evidence from 92 impact evaluations of FFS related to IPM found a 13% increase in yield and 20% increase in income following engagement with FFS (4). A specific application of agroecological principles for IPM is *push-pull*, which is yielding notable successes from redesign of monocropped maize, millet and sorghum systems (5-6). Interplanting of the legume forage *Desmodium* suppresses *Striga* and repels stem borer adults while attracting natural enemies; planting *Napier* grass as a border crop pulls stem borer moths from the cereal. It is estimated that 132,000 farmers have adopted push-pull in Kenya, Uganda, Tanzania and Ethiopia (5). Positive externalities arise from nitrogen fixation by *Desmodium* and elimination of pesticides, in the provision of high quality fodder, enabling farmers to diversify into dairy and poultry production, in turn increasing the availability of animal manure for crops and soils. One meta-analysis of 85 IPM projects found a mean yield increase across projects and crops of 41%, combined with a decline in pesticide use to 31% compared with the baseline (7); another multi-country study of SI in rice-based systems of China, Thailand and Vietnam found yield increases of 5% with pesticide use reductions of 70% (8).

Type 2. Conservation Agriculture

A central principle of this redesign type is improved soil health. A variety of measures to mitigate soil erosion, improve water-holding capacity and increase soil organic matter are being deployed to improve soil health and boost crop yields. Three key features are reduced soil disturbance through reduced or zero tillage, mulching and green manures, and maintenance of year-round soil cover and crop rotations, seeking to maintain an optimum environment in the root zone in terms of water availability, soil structure and biotic activity (9-11). Optimal CA uses all three features, though many farmers only practice one or two of these. Currently, CA systems are practiced across a range of agro-ecological conditions, soil types and farm sizes. CA practices are spreading by some 6 Mha annually to a total of 180 Mha in 2017. CA covers >50% arable cropland in Australasia and South America, 15% of North America, though adoption has been lower across Europe and Africa.

Type 3. Integrated Crop and Biodiversity Redesign

In both industrialised and developing countries, a growing number of crop systems have been redesigned using agro-ecological principles. A worldwide example of redesign is organic agriculture, now occupying 58 Mha, with yields 5-50% lower than conventional equivalents, though under certain conditions organic yields can match or exceed conventional (12-14). With a wide range of approaches including livestock, pasture, agroforestry and small-scale horticulture, many organic systems have higher biodiversity, landscape diversity and soil carbon, and lower soil erosion and contamination of water systems (15), though some of these benefits come from uncultivated habitats. However, organic systems are generally more profitable, thanks in part to legally-regulated markets, and environmentally friendly, and deliver equally or more nutritious foods that contain fewer pesticide residues. Over the past decade, the number of organic producers has grown by 55% and organic area doubled, and there have been recent calls for a *beyond organic* or *organic 3.0*, focusing on sustainability goals rather than market definitions (12, 16-17). The largest number of organic farmers are in India, Ethiopia, Mexico and Uganda; the largest area in Australia and Argentina, and the largest proportions of country cropland in Austria, Liechtenstein and Samoa (13).

Further redesign and deployment of multiple interventions has seen increased rotational diversity, use of wildflowers for pollinators and other beneficial insects, conservation headlands and trap crops, composted animal manures, and grain legumes (18-20), often with large reductions in input use without yield compromise, such as on 750 farms in France (21). In less-developed countries, fish, crab, turtle and duck have been reintroduced into rice systems, reducing pest and weed incidence, often eliminating the need for pesticides, and thus producing increased system productivity through new animal protein (22). Both the Systems of Rice and Crop Intensification (SRI and SCI) emerged from complete redesign of paddy rice cultivation: reduced planting density, improvement of soil with organic matter, reduced use of water, and very early transplantation of young plants have led to considerable yield increases with reduced requirements for water and other external inputs (23-24). Since inception, SRI principles have been adapted from rice to wheat, sugarcane, tef, finger millet and pulses, all again emphasizing changes in resource use and application combined with crop planting design. The governments of Cambodia, China, India, Indonesia and Vietnam have endorsed SRI/SCI methods in their national food security programmes, with one million Vietnamese rice farmers now using SRI.

Type 4. Pasture Redesign

Pasture redesign has arisen from diversification of cropping, including organic agriculture, the adoption of Management Intensive Rotation Grazing (MIRG), and the deployment of agro-pastoral field schools (25). In Brazil, redesigned *Brachiaria* forages in maize-rice and millet-sorghum systems have through increased net productivity led to large increases in all-year forage, which is used both for livestock and as a green manure (26). MIRGs are an example of widespread pasture redesign, using short-duration grazing episodes on small paddocks or temporarily fenced areas, with longer rest periods that allow grassland plants to regrow before grazing returns (27). These systems replace external inputs including feed with knowledge and high levels of active management to maintain grassland productivity. Well-managed grazing systems have been associated with greater temporal and spatial diversity of plant species, increased carbon sequestration, reduced soil erosion, improved wildlife habitat and decreased input use (28). As many have replaced zero-grazed confined livestock systems, the animals themselves have to be bred for different characteristics: large mouth, shorter legs, stronger feet and hooves, larger rumen. MIRGs were first developed in New Zealand, and are now common in parts of the USA.

Type 5. Trees in Agricultural Systems

Agroforestry has long been used in traditional agricultural systems, particularly in the tropics (29). Two types of deliberate redesign have been deployed with trees and shrubs: i) their introduction into cropped systems, and ii) new forms of collective management of woodland and forest within agricultural landscapes. Legume tree-based farming systems offer a route to increased availability of nitrogen while avoiding synthetic fertilizers, leading to the use of the term *fertilizer tree* (30). Shrubs (e.g., *Gliricidia, Sesbania*) are introduced into crop rotations, increasing fuelwood production and nitrogen fixation, but still increasing net cereal yield over a five-year rotation. In other systems, perennial trees (e.g., *Faidherbia*) are introduced into dryland and silvo-pastoral systems, with trees leafing when crops are not growing, resulting in re-greening of some 5Mha in Niger, Burkina Faso and Mali, with the outcome of amended local climate, increased wood and tree fodder availability, and better water harvesting (31-32). The success of community-based, joint and participatory forest management has centered on the reversal of past state policy to exclude local people. Local management through new forest institutions, plus devolution of practices, rules and sanctions, have led to the formation of 3000 groups in Mexico, 30,000 in India and Nepal, 1.8M farmers in Vietnam with tree certificates, and 12M forest farmer cooperative users in China (33-34). There is renewed interest in agroforestry in temperate systems, particularly in France and the UK (16).

Type 6. Irrigation Water Management

Without regulation or control, irrigation water tends to be overused by those who have first access, resulting in shortages for tail-enders, conflicts over water allocation, and waterlogging, drainage and salinity problems (34). However where social capital is well-developed, water-user groups with locally developed rules and sanctions are able to make more of existing resources than individuals working alone or in competition (35-36). This increases rice yields, farmer contributions to design and maintenance of systems, changes in the efficiency and equity of water use, decreased breakdown of systems and fewer complaints to government departments. More than 60,000 water-user groups and associations have been established in India, Indonesia, Mexico, Nepal, Pakistan, the Philippines, Sri Lanka, Turkey and Uzbekistan, though many exist only on paper or remain in inefficient centralised control (37-42).

Type 7. Intensive Small and Patch Systems

The intensive use of patches (small areas of land) can be effective, particularly for cultivation of vegetables or rearing fish, poultry or small livestock. These may be located in gardens, at field boundaries, in urban or rural landscapes, and managed individually or collectively. Examples in industrialised countries include allotments, community gardens or farms, vertical and urban farms, and community supported agriculture. In developing countries, patch intensification for aquaculture ponds and tanks has been shown to raise protein production, reduce nitrogen requirements for crops, and positively impact agricultural productivity (43). Raised beds for vegetables in East Africa have been beneficial for large numbers of women, homestead garden production has spread in Bangladesh, and in China full redesign has been exemplified by integrated vegetable and fruit, pig and poultry farms with biogas digesters. Farm plots are very small (0.14 ha), and yet farmers are able to recycle wastes, produce methane for cooking, and reduce burning of wood and crop residues, with implementation on 50 M household plots in China (44-46). An important enabler of small-scale intensification has been provided by access to microcredit. When local groups are trusted to manage financial resources, they are more effective than banks, leading to positive agricultural and community outcomes. All form social groups, all work primarily with women, and all members of groups save money every week in order to create the capital for lending. In Bangladesh, Grameen Bank, Bangladesh Rural Advancement Committee, and Proshika have 1.5M groups with 17M members: many have diversified into social enterprises for rural artisans, providing livestock insemination services, chicken for retail, cold storage for potato farmers, dairy milk processing, services for fish farmers, tree seedlings, iodised salt, seed services, and sericulture (silk production) (47-49).

Supplementary Table S1. Global assessment of sustainable intensification redesign from 47 initiatives at scale

Redesign type	Illustrative sub-types	Country	Farm numbers (million)	Hectares under SI (million)
1. Integrated pest management (IPM) [50-59]	Farmer field schools for integrated pest management	Worldwide, 90 countries in Asia and Africa: especially Indonesia, Philippines, China, Vietnam, Bangladesh, India, Sri Lanka, Nepal, Burkina Faso, Senegal, Kenya	19.0	15.0
	Biological control of pearl millet head miner	Burkina Faso, Niger, Mali, Senegal	0.75	2.0
	Cotton integrated pest management	Egypt	0.15	0.31
	Push-pull IPM	Kenya, Uganda	0.13	0.10
2. Conservation agriculture [60-65]	Conservation agriculture with zero-tillage	Worldwide: Brazil, Argentina, Kazakhstan, USA, Australia, India		
		Industrialised countries	0.45	94.0
		Developing countries	16.5	86.0
	Microbacia groups for watershed management	Brazil, southern: Parana, Santa Catarina	0.10	1.0
	Zai and tassa water harvesting	Burkina Faso, Niger	0.05	0.025
3. Integrated crop and biodiversity redesign [66-83]	Organic agriculture	Worldwide: especially India, Ethiopia, Mexico (for numbers of farmers)	2.70	57.8
	Rice-fish systems	South-East and East Asia	1.0	1.4
	System of Crop and Rice Intensification, multiple crops	Ethiopia, Vietnam, India	3.113	3.013
	Pigeon pea/maize multiple cropping	East and Southern Africa	0.45	0.25
	Crop redesign with	Burkina Faso, Niger, Mali,	0.18	0.15

	integrated plant and pest management with farmer field schools	Senegal		
	Landcare	Australia	0.09	0*
	Campesino a Campesino agro-ecological farming	Cuba	0.10	0.05
	Zero-budget natural farming	India: Andhra Pradesh	0.163	0.081
	Farmer agro-ecological wisdom networks	NE Thailand	0.10	0.30
	Science and technology boards	China	0.05	0.03
	Legume-maize intercrops for green manures/cover crops	Honduras, Guatemala, Mexico, Nicaragua	0.067	0.090
	Green manure/cover crop mixed systems	Brazil	0.14	0.10
	All crops with mucuna legumes (for *Imperata* suppression)	Benin	0.014	0.03
	Mokichi Okada natural/nature farming	Japan	0.015	0.003
	Orange-fleshed short-duration sweet potato	Uganda	0.014	0.011
4. Pasture and forage redesign [84-88]	Management intensive rotational grazing	USA	0.01	1.6
	Brachiaria-grass mixed crop-forage systems	Brazil	1.3	80.0
	Agro-pastoral field schools	Uganda	0.12	0.25
5. Trees in agricultural systems [89-100]	Agroforestry and soil conservation	Niger, Burkina Faso, Mali	4.0	3.0
	Joint forest management groups and forest protection committees	India, Nepal	11.6	25.0
	Community based forestry	Mexico	0.09	15.0
	Forest farmer cooperatives	China, Vietnam	13.80	17.8
	Agroforestry and multifunctional agriculture	Cameroon	0.010	0.005
	Fertilizer and fodder trees and shrubs	Zambia, Malawi	0.50	0.40
6. Irrigation water management [101-104]	Water user associations for irrigation management	India	15.0	15.0
	Community irrigation management subaks	Indonesia (Bali)	0.90	14.0
	Water users associations	Mexico	2.0	4.0
7. Intensive small and patch systems [105-116]	Microcredit group programmes (enablers of small-scale SI): BRAC, Grameen, Proshika	Bangladesh	17.0	8.50
	Intensive vegetable-pig systems with biodigesters	China	50.0	7.0
	Homestead garden production	Bangladesh	0.94	0.01
	Organic small-scale raised beds	Kenya	0.15	0.001
	Allotment gardens	UK	0.30	0.0075

	Community urban gardens	USA and Canada	0.018	0.001
	Group purchasing associations (Community Supported Agriculture, tekei groups, guilds)	USA, France, Japan, Switzerland, Belgium	0.011	0.055
	Integrated aquaculture	Malawi, Cameroon, Ghana	0.018	0.001
Total			**163**	**453**

Note: we do not present data on adoption of GM crops here, as these have mostly resulted in Efficiency/Substitution changes: one crop variety for another, some reductions in insecticide, some increases in herbicide, depending on the traits (Frisvold and Reeves, 2014); a number of GM traits are used in conservation agriculture systems.
*The average farm size in Australia is 3000 hectares, but there is no data on area under SI within Landcare groups and farms.

References for Supplementary Text and Table

References for Supplementary Text

1. Kenmore P., Carino F., Perez G. and Dyck V. 1984. Population regulation of the rice brown plant hopper Nilaparvata lugens (Stal) within rice fields in the Philippines. *J. Plant Protect. Trop*. *1*, 19–38
2. Braun A. and Duveskog D. 2009. *The Farmer Field School Approach – History, Global Assessment and Success Stories*. IFAD: Rome
3. FAO 2016. *Farmer Field School Guidance Document*. Rome
4. Waddington, H., Snilstveit, B., Hombrados, J., Vojtkova, M., Phillips, D., Davies, P. et al. 2014. Farmer field schools for improving farming practices and farmer outcomes in low- and middle-income countries: a systematic review. Campbell Syst. Rev. 10, 1–335
5. Khan Z R, Midega C A O, Hooper A and Pickett J A. 2016 Push-Pull: chemical ecology-based integrated pest management technology. *Journal of Chemical Ecology* 42, (7) 689 – 697
6. Dicks, L.V., Wright, H.L., Ashpole, J.E., Hutchison, J., McCormack, C.G., Livoreil, B., Zulka, K.P. and Sutherland, W.J., 2016. What works in conservation? Using expert assessment of summarised evidence to identify practices that enhance natural pest control in agriculture. *Biodiversity and Conservation*, *25*(7), 1383-1399
7. Pretty J and Bharucha Z P. 2015. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. *Insects* 6, 152-82
8. Gurr, G.M., Lu, Z., Zheng, X., Xu, H., Zhu, P., Chen, G., Yao, X., Cheng, J., Zhu, Z., Catindig, J.L. and Villareal, S., 2016. Multi-country evidence that crop diversification promotes ecological intensification of agriculture. *Nature Plants*, *2*(3), p.16014
9. Kassam A., Friedrich T., Shaxson F. and Pretty J.N. 2009. The spread of conservation agriculture: justification, spread and uptake. *Int J Agric Sust* 7(4), 292-320
10. Kassam A, Friedrich T and Derpsch R. 2017. Global spread of Conservation Agriculture: Interim update. 7th World Congress on CA, Rosario, Argentina
11. Ward P S, Bell A R, Droppelmann K and Benton T G. 2018. Early adoption of conservation agriculture practices: Understanding partial compliance in programs with multiple adoption decisions. *Land Use Policy 70*, 27-37
12. Reganold J.P. and Wachter J.M. 2016. Organic agriculture in the 21st century. *Nature Plants* 2(2): 15221
13. FiBL. 2018. *The World of Organic Agriculture 2018*. Research Institute of Organic Agriculture (FiBL), Frick, Switzerland
14. Seufert, V., Ramankutty, N. and Foley, J.A. 2012. Comparing the yields of organic and conventional agriculture. *Nature* 485(7397), p.229
15. Batary P, Baldi A, Kleijn D andTscharntke T. 2011. Landscape-moderated biodiversity effects of agri-environmental management – a metaanalysis. *Proceedings of the Royal Society B* 278**, 1**894–1902
16. Lampkin N.H., Pearce B.D., Leake A.R., Creissen H., Gerrard C.L., Girling R., Lloyd S., Padel S., Smith J., Smith L.G., Vieweger A. and Wolfe M.S. 2015. The role of agroecology in sustainable intensification. Report for the Land Use Policy Group. Organic Research Centre, Elm Farm and Game & Wildlife Conservation Trust
17. Muller, A., Schader, C., El-Hage Scialabba, N., Hecht, J., Isensee, A., Erb, K.H., Smith, P., Klocke, P., Leiber, F., Stolze, M. & Niggli, U. 2017. Can organic agriculture feed the world in 2050: a critical assessment of the challenges and opportunities. *Nature Communication*s 8, 1290. doi: 10.1038/s41467-017-01410-w.
18. MacWilliam S, Wismer M, Kulshreshtha S (2014). Life cycle and economic assessment of Western Canadian pulse systems: The inclusion of pulses in crop rotations. Agricultural Systems 123:43- 53

19. Pywell R.F., Heard M.S., Woodcock B.A., Hinsley S., Ridding L., Nowakowski M. and Bullock J.M. (2015) Wildlife friendly farming increases crop yield: evidence for ecological intensification. *Proc Royal Society Lond*. B 282: 20151740
20. Franke, A.C., Van den Brand, G.J., Vanlauwe, B. and Giller, K.E. 2017. Sustainable intensification through rotations with grain legumes in Sub-Saharan Africa: A review. *Agriculture, Ecosystems & Environment*
21. Lechenet M, Dessaint F, Py G, Makowski D and Munier-Jolain N, 2017. Reducing pesticide use while preserving crop productivity and profitability on arable farms. *Nature Plants*, *3*, 17008
22. FAO. 2014. *Aquatic biodiversity in rice-based ecosystems: Studies & reports from Indonesia, LAO PDR and the Philippines.* M. Halwart & D. Bartley (ed). Asia Regional Rice Initiative: Aquaculture and fisheries in rice-based ecosystems. Rome
23. Stoop W, Uphoff N and Kassam A. 2002. A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. *Agric Systems* 71(3), 249-274
24. Adhikari P, Araya H, Aruna G, Balamatti A, Banerjee S, Baskaran P, Barah B C. Behera D, Boruah P, Dhar S, Edwards S, Fulford M, Gujja B, Ibrahim H, Kabir H, Kassam A, Khadka R B, Koma Y S, Natarajan U S, Perez R, Sen D, Sharif A, Singh G, Styger E, Thakur A, Tiwari A, Uphoff N and Verma A. 2018. System of Crop Intensification for more productive, resource-conserving, climate-resilient and sustainable agriculture: Experience with diverse crops in varying agroecologies. *International Journal of Agricultural Sustainability* (in press)
25. FAO. 2013. *Supporting Communities in Building Resilience Through Agropastoral Field Schools*. Rome
26. FAO 2011. *Save and Grow: A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production*. Rome
27. NRC 2010. *Towards sustainable agricultural systems in the 21st century*. Committee on Twenty-First Century Systems Agriculture. Washington, DC: National Academies Press
28. Sprague, R., Boyer, S., Stevenson, G.M. and Wratten, S.D., 2016. Assessing pollinators' use of floral resource subsidies in agri-environment schemes: An illustration using Phacelia tanacetifolia and honeybees. *PeerJ*, *4*, p.e2677
29. Lorenz K and Lal R. 2014. Soil organic carbon sequestration in agroforestry systems: a review. *Agronomy for Sustainable Development* 34: 443–454
30. Garrity D.P., Akinnifesi F.K., Ajayi O.C., Weldesemayat S.G., Mowo J.G., Kalinganire A., Larwanou M. and Bayala J. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. *Food Security* 2:197-214
31. Sendzimir J C P, Reij C and Magnuszewski P. 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. *Ecology and Society* 16(3): 1
32. Bunch R. 2018 (2012). *Restoring the Soil*. Canadian Foodgrains Bank, Winnipeg, 2nd edition
33. FAO. 2016. *Forty Years of Community-Based Forestry*. Rome: FAO.
34. Liu J and Innes J L. 2015. Participatory forest management in China: key challenges and ways forward. *Int Forestry* Review 17(2) 1-8
35. Molle, F., Foran, T. and Kakonen, M. eds., 2012. Contested waterscapes in the Mekong region: Hydropower, livelihoods and governance. Earthscan
36. Ostrom, E. 1990. Governing the commons: the evolution of institutions for collective action. Cambridge, UK, Cambridge University Press
37. Wang Xihua, Lu Wenxi, Xu Y J, Zhang G, Qu W and Cheng W. 2016. The positive impacts of irrigation schedules on rice yield and water consumption: synergies in Jilin Province, Northeast China. *Int J Agric Sust* 14:1, 1-12
38. Shindo S and Yamamoto K. 2017. Strengthening water users' organization targeting for participatory irrigation management in Egypt. *Paddy and Water Environment 15*(4), 773-785
39. Uysal Ö K and Atış E. 2010. Assessing the performance of participatory irrigation management over time: A case study from Turkey. *Agricultural water management*, *97*(7), 1017-1025
40. Sinha P. 2014. Status of Participatory Irrigation Management (PIM) in India. *National Convention of Presidents of Water Users Associations,* Ministry of Water Resources India NPIM, New Delhi, 7-8 November, 2014
41. Zhou Q, Deng X., Wu F., Li Z. and Song W., 2017. Participatory irrigation management and irrigation water use efficiency in maize production: evidence from Zhangye City, Northwestern China. *Water*, *9*(11), 822
42. Ricks J.I. 2016. Building participatory organizations for common pool resource management: Water user group promotion in Indonesia. *World Development 77*, 34-47
43. Brummett R E and Jamu D M. 2011. From researcher to farmer: partnerships in integrated aquaculture-agriculture systems in Malawi and Cameroon. *Int J Agric Sust* 9(1), 282-289
44. Iannotti L, Cunningham K, Ruel M. 2009. Improving diet quality and micronutrient nutrition: homestead food production in Bangladesh. IFPRI Discussion Paper 00928. Washington, DC: International Food Policy Research Institute
45. Pretty J, Toulmin C, Williams S. 2011. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability 9(1): 5-24
46. Gu L, Zhang Y-X, Wang J-Z, Chen G and Battye H. 2016. Where is the future of China's biogas? Review, forecast, and policy implications. *Petroleum Science*. 13 (1), 604–624
47. BRAC. 2017. www.brac.net
48. Grameen Bank. 2017. URL www.grameen.com
49. Proshika 2017. URL www.proshika.org

Integrated Pest Management

50. Braun A. and Duveskog D. 2009. *The Farmer Field School Approach – History, Global Assessment and Success Stories*. IFAD: Rome
51. Chhay N, Suon Seng, Toshiharu Tanaka, Akira Yamauchi, Editha C. Cedicol, Kazuhito Kawakita & Sotaro Chiba (2017) Rice productivity improvement in Cambodia through the application of technical recommendation in a farmer field school, International Journal of Agricultural Sustainability, 15:1, 54-69
52. FAO 2016. *Farmer Field School Guidance Document*. FAO: Rome.
53. ICIPE 2013. Stories of our success: positive outcomes from push-pull farming systems. http://www.push-pull.net/farmers_success.pdf
54. Khan Z.R., Midega C., Pittchar J.O., Murage A and Pickett J. 2017. Climate-smart Push-Pull: A conservation agriculture technology for food security and environmental sustainability in Africa. CAB International
55. Khan, Z.R., Midega, C.A.O., Hooper, A.,Pickett, J.A. 2016 Push-Pull: Chemical Ecology-Based Integrated Pest Management Technology. Journal of Chemical Ecology 42, (7) 689 – 697
56. Payne, W., Tapsoba, H., Baoua, I. B., Malick, B. N., N'Diaye, M., Dabire-Binso, C. 2011. On-farm biological control of the pearl millet head miner: realization of 35 years of unsteady progress in Mali, Burkina Faso and Niger. International Journal of Agricultural Sustainability 9(1), 186–193
57. Pretty J and Bharucha Z P. 2015. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. *Insects* 6, 152-82
58. Pretty J, Toulmin C, Williams S. 2011. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability 9(1): 5-24
59. Yang P.Y., Zhao Z.H. and Shen Z.R. 2014. Experiences with Implementation and Adoption of Integrated Pest Management in China. In Integrated pest management (pp. 307-330). Springer Netherlands

Conservation Agriculture

60. Bunch R. 2018 (2012). *Restoring the Soil*. Canadian Foodgrains Bank, Winnipeg
61. Derpsch R., Friedrich T., Kassam A. and Hongwen L. 2010. Current status and adoption of no-till farming in the world and some of its main benefits. *Int. J. Agric. & Biol Eng* 3(1): 1-25
62. Kassam A, Friedrich T and Derpsch R. 2017. Global spread of Conservation Agriculture: Interim update. 7th World Congress on CA, Rosario, Argentina
63. Kassam A., Friedrich T., Shaxson F. and Pretty J.N. 2009. The spread of conservation agriculture: justification, spread and uptake. *International Journal of Agricultural Sustainability* 7(4): 292-320
64. Li Hongwen, He Jin, Bharucha Z P, Lal R and Pretty J. 2016. Improving China's food and environmental security with conservation agriculture. *International Journal of Agricultural Sustainability* 14, 377-391
65. Sawadogo H. 2011. Rehabilitation of degraded lands by using soil and water conservation techniques in the north western region of Burkina Faso. *International Journal of Agricultural Sustainability* 9(1): 120-128.

Integrated crop and biodiversity redesign

66. Adhikari P, Araya H, Aruna G, Balamatti A, Banerjee S, Baskaran P, Barah B C. Behera D, Boruah P, Dhar S, Edwards S, Fulford M, Gujja B, Ibrahim H, Kabir H, Kassam A, Khadka R B, Koma Y S, Natarajan U S, Perez R, Sen D, Sharif A, Singh G, Styger E, Thakur A, Tiwari A, Uphoff N and Verma A. 2018. System of Crop Intensification for more productive, resource-conserving, climate-resilient and sustainable agriculture: Experience with diverse crops in varying agroecologies. International Journal of Agricultural Sustainability (in press)
67. Bunch R. 2018 (2012). *Restoring the Soil*. Canadian Foodgrains Bank, Winnipeg
68. FAO 2011.*Save and Grow: A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production*. Rome: FAO
69. FAO 2016a. *Save and Grow: Maize, Rice and Wheat – A Guide to Sustainable Crop Production,*UN Food and Agriculture Organization, Rome
70. FiBL, 2017. *The World of Organic Agriculture 2017*. Research Institute of Organic Agriculture (FiBL), Frick, Switzerland
71. Holt-Gimenez E and Altieri M A. 2013. Agroecology, food sovereignty, and the new green revolution. Agroecology and Sustainable Food Systems 37: 90–102
72. Kumar V. T. 2017. Zero-Budget Nature Farming. Department of Agriculture , Government of Andhra Pradesh, Hyderabad
73. Mwanga R O M and Ssemakula G. 2011.Orange-fleshed sweet potatoes for food, health and wealth In Uganda. International Journal of Agricultural Sustainability 9(1), 42–49
74. Pretty J, Toulmin C, Williams S. 2011. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability 9(1): 5-24
75. Pretty J.N. and Bharucha Z P. 2014. Sustainable intensification in agricultural systems. *Annals of Botany* 205, 1-26.
76. Reganold J.P. and Wachter J.M. 2016. Organic agriculture in the 21st century. *Nature Plants* 2(2): 15221
77. Rosset P.M. and Martínez-Torres M.E. 2012. Rural Social Movements and Agroecology: Context, Theory, and Process. *Ecology and Society* 17(3): 17.

78. Rosset, P.M., Machín Sosa, B., Roque Jaime, A.M. and Ávila Lozano, D.R., 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty. The Journal of peasant studies, 38(1), pp.161-191
79. Rosset, P.M., Machín Sosa, B., Roque Jaime, A.M. and Ávila Lozano, D.R., 2011. The Campesino-to-Campesino agroecology movement of ANAP in Cuba: social process methodology in the construction of sustainable peasant agriculture and food sovereignty. *The Journal of peasant studies*, *38*(1), pp.161-191
80. Settle W and Hama Garba M., 2011. The FAO integrated production and pest management programme in the Senegal and Niger river basins of francophone West Africa. International Journal of Agricultural Sustainability 9(1), 171–185
81. SRI-Rice (2014). The System of Crop Intensification: Agroecological Innovations for Improving Agricultural Production, Food Security, and Resilience to Climate Change. SRI International Network and Resources Center (SRI-Rice), Cornell University, Ithaca, New York, and the Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, Netherlands
82. Xu, Hui-lian. 2006. *Nature Farming*. Research Signpost 37/661, Trivandrum, Kerala
83. Zhang W., Cao G., Li X., Zhang H., Wang C., Liu Q., Chen X., Cui Z., Shen J., Jiang R. and Mi G. 2016. Closing yield gaps in China by empowering smallholder farmers. *Nature* 537(7622): 671-674

Pasture and forage redesign

84. CIAT. 2016.Livestock, climate change and Brachiaria. Eco-Efficient Agriculture for the Poor. CIAT Brief 12. www.ciat.cgiar.org
85. FAO 2011.*Save and Grow: A Policymaker's Guide to the Sustainable Intensification of Smallholder Crop Production*. Rome: FAO
86. FAO. 2013. *Supporting Communities in Building Resilience Through Agropastoral Field Schools*. Rome
87. NRC 2010. Towards sustainable agricultural systems in the 21st century. Committee on Twenty-First Century Systems Agriculture. Washington, DC: National Academies Press Ostrom, E. 1990. Governing the commons: the evolution of institutions for collective action. Cambridge, UK, Cambridge University Press
88. Pretty J.N. 2014. *The Edge of Extinction*. Ithaca and London: Cornell University Press

Trees in agricultural systems

89. Ajayi O C, Place F, Akinnifesi F K and Sileshi G W. 2011. Fertilizer tree systems in Southern Africa (Malawi, Tanzania, Mozambique, Zambia and Zimbabwe). *International Journal of Agricultural Sustainability* 9(1), 129–136
90. Asaah, E. K., Tchoundjeu, Z., Leakey, R. R. B., Takousting, B., Njong, J., Edang, I., 2011, 'Trees, agroforestry and multifunctional agriculture in Cameroon', International Journal of Agricultural Sustainability 9(1), 110–119
91. Blomley, T. 2013. Lessons learned from community forestry in Africa and their relevance for REDD+. Washington, DC, Forest Carbon, Markets and Communities Program
92. Bunch R. 2018 (2012). *Restoring the Soil*. Canadian Foodgrains Bank, Winnipeg
93. FAO. 2016c. *Forty Years of Community-Based Forestry*. Rome: FAO.
94. Garrity D.P., Akinnifesi F.K., Ajayi O.C., Weldesemayat S.G., Mowo J.G., Kalinganire A., Larwanou M. and Bayala J. 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Security 2:197-214
95. Liu, J. and Innes, J.L. 2015. Participatory forest management in China: key challenges and ways forward. International Forestry Review, 17(2): 1-8.
96. Liu, J. and Innes, J.L. 2015. Participatory forest management in China: key challenges and ways forward. International Forestry Review, 17(2): 1-8.
97. Ministry of Forest and Soil Conservation, Nepal (MFSC). 2013. Persistence and change: review of 30 years of community forestry in Nepal. Kathmandu
98. Reij C.P. and Smaling E.M.A. 2008. Analyzing successes in agriculture and land management in Sub-Saharan Africa: Is macro-level gloom obscuring positive micro-level change? *Land Use Policy* 25: 410–420
99. Sendzimir J.C.P., Reij C. and Magnuszewski P. 2011. Rebuilding resilience in the Sahel: regreening in the Maradi and Zinder regions of Niger. Ecology and Society 16(3): 1
100. Wahl C T and Bland W L. 2013. Faidherbia albida on the Tonga Plateau of southern Zambia: an agroecological analysis, International Journal of Agricultural Sustainability 11 (4) 382-392

Irrigation water management

101. Shindo, S. and Yamamoto, K., 2017. Strengthening Water Users' Organization targeting for Participatory Irrigation Management in Egypt. *Paddy and Water Environment*, *15*(4), 773-785
102. Sinha P. 2014. Status of Participatory Irrigation Management (PIM) in India. *National Convention of Presidents of Water Users Associations,* Ministry of Water Resources India NPIM, New Delhi, 7-8 November, 2014
103. Uysal Ö K and Atış E. 2010. Assessing the performance of participatory irrigation management over time: A case study from Turkey. *Agricultural water management*, *97*(7), 1017-1025
104. Yekti, M.I., Schultz, B., Norken, I.N., Gany, A.H.A. and Hayde, L., 2017. Learning from Experiences of Ancient Subak Schemes for Participatory Irrigation System Management in Bali. *Irrigation and Drainage*, *66*(4), pp.567-576.

Intensive small scale systems

105. AMAP (Associations pour le maintien d'une agriculture paysanne) 2017. www.reseau-amap.og
106. American Community Gardening Association 2014. https://communitygarden.org/resources/faq/
107. American Community Gardening Association. 2014. https://communitygarden.org/resources/faq/
108. BRAC. 2017. www.brac.net
109. Brummett R E and Jamu D M. 2011. From researcher to farmer: partnerships in integrated aquaculture-agriculture systems in Malawi, Ghana and Cameroon. International Journal of Agricultural Sustainability 9(1), 282–289
110. Grameen Bank. 2017. URL www.grameen.com
111. Gu L, Zhang Y-X, Wang J-Z, Chen G and Battye H. 2016. Where is the future of China's biogas? Review, forecast, and policy implications. Petroleum Science. 13 (1), 604–624
112. Iannotti L, Cunningham K, Ruel M. 2009. Improving diet quality and micronutrient nutrition: homestead food production in Bangladesh. IFPRI Discussion Paper 00928. Washington, DC: International Food Policy Research Institute.
113. National Allotment Society 2014. Brief history of allotments. http://www.nsalg.org.uk/allotment-info/brief-history-of-allotments/
114. Pretty J and Bharucha Z P. 2015. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. *Insects* 6, 152-82
115. Proshika 2017. URL www.proshika.org
116. USDA 2016. Farmers' Market Promotion Program. 2016 Report. Connecting Rural & Urban Communities. URL: https://www.ams.usda.gov/reports/farmers-market-promotion-program-2016-report