How to overcome the slow death of intercropping in China

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Abstract: *Intercropping has a strong potential to slow down the severe degradation of arable land, many parts of China experienced in the last decades. Recent research findings proved the agronomic and environmental advantages of intercropping systems in the region. However the question remains whether this traditional production system fits the demands of modern agriculture and how it has to be adjusted to do so. To identify prevailing intercropping systems and understand farmers underlying motives and concepts a qualitative inquiry was conducted in the North China Plain. Furthermore farmers, extensionists, and researchers were interviewed on the future of intercropping. Additionally statistical data was consulted to understand current trends and future developments of the socio-economic and technical frame conditions. The investigations revealed that the limited off-farm income possibilities in rural China make intercropping a viable solution to intensively use the limited land resources of less than 0.5 hectare per farm household for income generation. However, a shift of rural laborers into the construction and industrial sector can be observed in recent years. Thus decreasing importance of income from agriculture and increasing labor costs are heralding the slow death of labor intensive intercropping systems. There is an urgent need to develop and disseminate systems that can be mechanized. We conclude that only an integrative research approach that includes all stakeholders is able to adjust the intercropping systems to future demands. Only systems that serve farmers' requirements can considerably benefit the environment.*

Keywords: *intercropping, mechanization, China*

Background

Agriculture in China has experienced strong production and yield increases in the last decades (CSY, 2008). This is a great success for China's agricultural policy which very much focuses on food security. However, one has to be aware that the strong production increases are mainly a result of increased inputs of fertilizer, irrigation water and plant protection (HSY, 2008). The input levels have finally reached the upper limit, both in terms of further yield increases and environmental capacity. Water and land resources are often degrading in a severely unsustainable way. As a result groundwater tables are depleting (Jia et al., 2002), soils are eroding (Chen, 2007) and agrochemical residues in ground and surface water are accumulating (Li et al., 2009). One might assume that in rapidly developing China most of the arable land is lost through industrialization, urbanization and construction of infrastructure. Those losses are tremendous, but can hardly be compared to the losses of arable land caused by unsustainable agricultural production as reported by Brown (1995) and Chen (2007). To maintain the production base for future generations there is an urgent need to develop and disseminate more sustainable agricultural systems.

A production system that has a strong potential to counteract resource degradation while maintaining high yield levels is intercropping. The simultaneous cultivation of two or more crops on the same field is a traditional system in China (Chandler, 1994; Knoerzer et al., 2009; Li, et al. 2006). By a more efficient use of the growth factors water, nutrients, and solar radiation, intercropping often overyields its monocropping equivalents (Alene and Hassan, 2003; Carrubba et al., 2008). When combining different crop types, weed and pest pressure are lowered and input of herbicides and pesticides can be reduced (Baumann et al., 2000; Hatcher and Melander, 2003). All in all intercropping can lead to higher yields while saving resources, controlling erosion and reducing nutrient leaching (Wahua, 1985; Whitmore and Schroeder, 2007).

In recent years the number of publications on intercropping in China has increased strongly (e.g. Zhang and Li, 2003; Li et al., 2004; Gao et al., 2009). Several research groups examined various aspects of intercropping systems with a focus on the North China Plain region, which is a major agricultural production region. Research concentrated on agronomic aspects of the systems, mainly yield advantages and below ground resource capture. The results significantly contributed to increase the knowledge on various agronomic aspects of intercropping systems in China and worldwide.

However, one important question was still insufficiently answered after intensive literature review: What is the actual importance of intercropping in China? When it is about land under intercropping cultivation, unfortunately most papers either refer to sources written in Chinese, published in the beginning of the 1990s, (e.g. Zhang and Li, 2003) or even do not clarify where the information originates from (e.g. Li et al., 2001). When we compare the often cited estimations of Tong (1994), of "one third of all Chinese grain being produced in intercropping systems" to our field observations, we identify a huge gap. After ten months of field research including extensive travels to most parts of the North China Plain, we would reduce the former estimations to around five percent of arable land being under intercropping cultivation. Irrespective slight overestimations beginning of the 1990s, we have to assume that the area under intercropping cultivation, and thus the importance of intercropping strongly decreased in the last two decades.

Aims and methods

The potential of intercropping as a resource saving and high yielding production system is beyond question. All the more it is of great importance to understand why intercropping is losing ground in contemporary China and what could be done to reverse this trend. The rapidly changing frame conditions in rural China have a strong impact on farmers' decision making and hence farming systems. In the first step the current situation of intercropping practices in the North China Plain is evaluated. Therefore a qualitative inquiry was conducted, interviewing farmers, employees of the state extension service and researchers involved in intercropping research. The inquiry had several goals: i) identify prevailing intercropping systems in the region, ii) understand farmers underlying motives and concepts, and iii) understand and describe how the systems are developed and distributed. Semi-structured in depth interviews, as described by Case (1990) were applied. The interviews with farmers focused on the agronomic details of the practiced intercropping system, the individual intercropping history, perceived benefits and drawbacks of the system and on the awareness of environmental connectivity. Additionally the interviews with researchers and extensionists addressed the generation and transfer of research findings as well as the perception of farmers' knowledge and motives. As the goal of the study was to obtain the greatest possible information from the cases in the sample, snowball sampling (Garforth and Usher, 1997) was applied. The survey was conducted in the Northern and central part of the North China Plain from October 2007 to April 2008 with the help of a previously trained interpreter. In total 35 farmers (21 intercropping, 14 non-intercropping), 10 extensionists and six researchers were interviewed. Due to the homogeneous environmental and socio-economic conditions of the North China Plain the sampling size is considered sufficient to create a sound picture of intercropping practices in the region. To ensure the relevance of the sampling structure, interviewees were selected to cover a wide range of intercropping systems, both in terms of crop combinations and input demand.

The rapidly changing frame conditions in rural China have a strong impact on farmers' decision making and hence farming systems. Based on the evaluation of data from the national and provincial statistical yearbooks, the developments in the socio-economic and socio-technical framework over the last decades were analyzed. By connecting the findings of the inquiry with the findings of the statistical data evaluation past developments are explained, future trends are predicted and conclusions are drawn on how to adjust the systems to make them fit future demands.

Figure 1. Map of mainland China with the location of the survey region North China Plain (NCP).

Results and Discussion

What farmers practice?

A huge variety of intercropping systems was identified in the region. Apart from various agroforestry systems, farmers practice pure cereal, cereal-legume, cereal-vegetable, cotton-vegetable, and pure vegetable systems. The systems are mainly relay intercropping systems, with one component crop being sown or planted into an already established crop. Only parts of their growing period the two component crops spend together in the field. For a better understanding two popular systems are illustrated (Fig. 2). In the winter wheat-maize system wheat is sown in fall, leaving bare strips of 10-20 cm width in a distance of around 80 cm. In spring approximately 50 days before harvest of wheat, maize is sown into the bare strips. When wheat is harvested the maize plants already developed approximately ten leaves and reached a height of 40-80cm. With this system two grain crops can be produced in one year. The onion-cotton system is widely practiced in Feixiang county, Hebei province. Onion is planted in autumn leaving 80 cm wide strips bare in between. Around 25th of April, a double row of cotton is sown under plastic mulch into the bare strips. The two companion crops then spend nearly six weeks together in the field, until onion is harvested.

Figure 2. Relay intercropping of maize with wheat in Shandong province (left) and relay intercropping of cotton with onion in Hebei province (right).

Why farmers practice?

In both systems as well as in most other systems farmers' main reason to practice the intercropping system is to make full use of their limited land resources. Rural farm households in China cultivate less then half a hectare in average (CSY, 2008), and often households solely depend on the income from agricultural activity. As a result of availability of abundant labor force in combination with scarce land resources, very complex intercropping systems which demand a huge input of manual labor evolved. These systems are often characterized by a very high land productivity and small labor productivity.

Additionally farmers report about reduced pest and disease pressure in their intercropping systems compared to monocropping. This not only saves input of pesticides, which reduces production cost and benefits the environment. Also, like in the case of chili-maize intercropping, dried chili of higher quality, which can fulfill export standards more easily, can be produced. To our surprise the often mentioned advantage, that intercropping can help to avoid the risk of crop failure (Iqdal et al., 2007; Rao and Willey, 1980) seems of no interest to Chinese farmers. We assume that the reliable supply of farm inputs already ensures high crop yields.

On the contrary farmers complain that intercropping is very labor demanding, both in quantity and quality. Not only farmers have to spend more time in the field, but they have to manage a very sophisticated cropping system. Throughout the cropping season management practices are getting more complex, like sowing or planting the second crop into an already established crop. Same holds true for the harvest of the crop which reaches maturity first, where farmers have to be very careful not to damage the remaining crop with the later harvest date. Here the harvested good has to be transported manually to the field border directly and can not be stored temporarily in the field.

What has changed?

The following chapter tries to reveal why the area under intercropping cultivation has strongly declined in the last two decades. The reasons are plentiful and highly interlinked. Above all the economic development led to strong changes in rural farm households' production factor endowment, what has a severe impact on cropping structures and farming systems.

Since the market reforms in the beginning of the 1980s China has experienced an accelerated economic growth. What started in the special economic zones on the east coast and spread inland via the metropolis Shanghai, Beijing and Guangzhou reaches nowadays even the most remote areas of the country. Not only did incomes increase steadily, the economic development also had tremendous impact on the labor market.

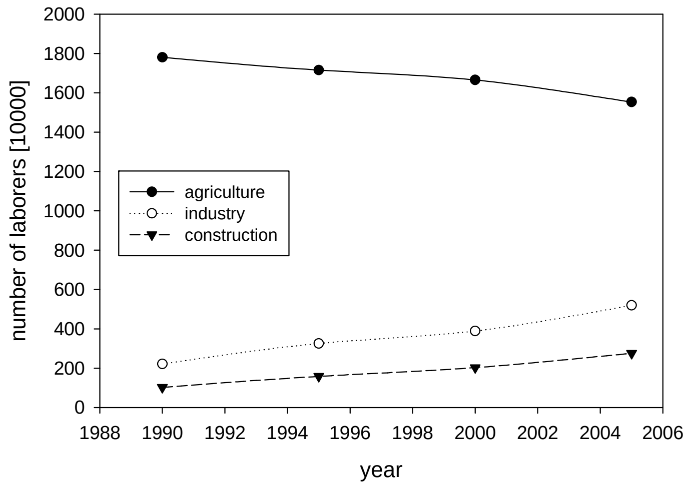

Figure 3. Development of the number of rural laborers per sector in Hebei province (HSY, 1999-2008, compiled by authors).

A lack of alternatives still predetermined most people's career as a farmer one generation ago. In contrast nowadays' youth often doesn't see its future tilling the family's fields. In Hebei province, as in all provinces of China the number of rural laborers, who generate most of their income from agriculture decreased steadily since the beginning of the 1990s. In 2007 the share of rural laborers fell below 60%. People mainly move into the industrial and construction sector (HSY, 1999-2008). Similarities can be found when looking at the share of income generated from agricultural production (Fig. 4). During the time of collectivization until 1980 the rural population was mainly employed in the state cooperatives, receiving a monthly salary. With the agricultural reforms however, land rights returned to farmers and farm households act as entrepreneurs, generating income from their fields. Since 1985, when the share of income generated from agricultural activity made up more then 90%, a steady decline is happening. In 2005 the share dropped below 70%.

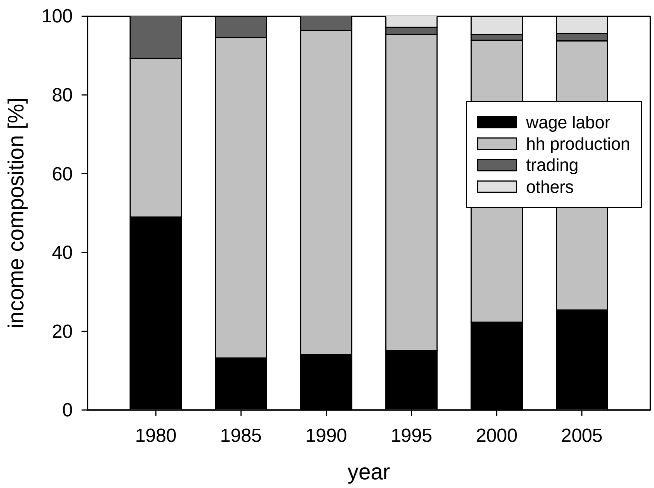

Figure 4. Income composition of rural households in China (CRHSY, 2007).

The production factor labor, which had been nearly inexhaustible available in rural China in the past is becoming scarcer and scarcer. In the last decades steadily increasing off-farm income possibilities lead to increasing opportunity costs and thus farm households invest less and less time to their fields.

Increasing household incomes, which for the first time in history made capital available as production factor, and reduced labor force in agriculture led to another phenomenon. The use of agricultural machinery is rapidly finding its way into Chinese agriculture. From 1985 to 2007 the number of tractors in Hebei province increased from 320000 to more than 1.5 million (Fig. 5). In recent years the increase in umber of small machinery is slowing down, while the number of medium and big machinery is steadily increasing.

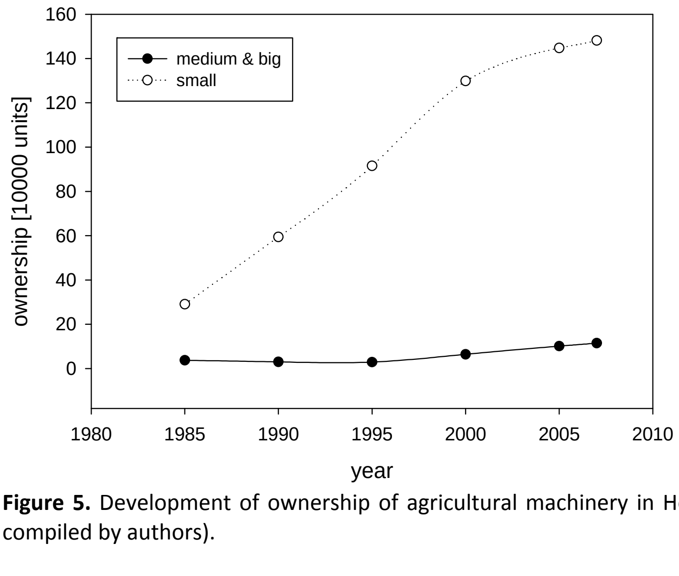

Figure 5. Development of ownership of agricultural machinery in Hebei province from 1985 until 2007 (HSY, 1999-2008, compiled by authors).

When looking at the production factor land, two points have to be differentiated: the development in total available land and the available land per farm household. Between 2000 and 2007 arable land resources in Hebei province declined from 6.9 million hectare to 6.3 million hectare (HSY, 2008). According to Tan (2005) arable land loss in China reached more than 300000 ha annually in the last two decades. However, part of the land loss is strongly connected to the economic development. Employment opportunities are created by both construction of infrastructure and industrial compounds, as it can be seen above (Fig. 3). Additionally this kind of land loss is concentrating around cities and development centers. As a consequence, most farm households are not affected by the land loss. This can also be seen in the development of farm land per household, which did not decrease significantly in the last decade (HSY, 2008).

Another aspect that is of vivid importance for the future of farming structures in China is the development of a land rental market. Until now, farmers do not own the land under cultivation, but they have long term use rights. The definitions of these use rights differ strongly between counties and villages, as we detected in our inquiry. In general farmers have the right to rent out their land. However, as detected by Piotrowski (2009) only a very small percentage of farmers are actually renting in and out land. We assume that farm households are anxious that the land use rights might be nullified by the local authorities, when it becomes obvious that the household doesn't depend on the land anymore.

This hesitance also maintains the extreme scatteredness of farmers' fields. The already small farm land is subdivided more than five small plots with an average size of 0.07 hectare. The strong land fragmentation evolved with the implementation of the household responsibility system beginning of the 1980s. Land within each village was classified in different quality categories and than allocated equally among farm households (Tan et al., 2006; Dou et al. 2007). On one side land fragmentation has very positive effects on agro-biodiversity, as it often occurs that different crops are grown in neighboring plots. On the other side production efficiency is constrained, which was also recognized by the national government to be hindering development possibilities. Thus land consolidation has been put on the agenda and set as an urgent task in the "eleventh five year plan" of the state council of the People's Republic of China (Dou et al., 2007). Radical changes are most likely not to happen in the near future (Tan et al., 2006). However, in the long run land fragmentation is going to reduce strongly (Wan, 2001).

What does this mean for intercropping?

Most intercropping systems in China are row intercropping systems with alternating rows of two different crops (Fig. 2). These systems significantly overyield their monocropping equivalents by a more efficient resource use and in the past enabled farmers to make optimal use of their limited land resources. With continuously increasing incomes and employment opportunities in the non-agricultural sectors, the shift in production factor endowment is also going to continue. The inquiry in the North China Plain revealed that intercropping systems are more widespread in remote regions with limited off-farm income possibilities compared to sub-urban regions, where farmers already generate a great part of their income off-farm. In case of the winter wheat-maize relay intercropping system rural farmers reported that, as the younger generation left to work as migrant workers, the traditional system was given up. Labor resources were insufficient to maintain it. In this context also the availability of new maize varieties with a shorter maturity time plays an important role. In many regions of the North China Plain winter wheat and maize can thus be cultivated one after the other in a double cropping system.

The availability of capital and scarcity of labor in rural China will lead to tremendous changes in agricultural production systems in general and intercropping systems in particular. The upcoming reform of land use rights and land consolidation will work as a catalyst in this respect, resulting in a further mechanization and also industrialization of agriculture. If intercropping as a resource saving system should be maintained on a larger scale, immediate action is to be taken.

How to adjust the cropping systems?

Two different paths can be followed to adapt intercropping production systems to future demands. Either the intercropping systems have to be adjusted in that way that at least part of the management practices can be accomplished by machines, or new machinery has to be developed that enables the mechanization of the traditional systems. The decision on which path to follow will mainly depend on the characteristics and demands of the two component crops in a certain system. In special cases also the combination of adjusting the system to be managed with adjusted machines might be the solution.

In most cases however, the traditional row systems will have to be transformed in strip systems. In strip intercropping positive effects were identified up to a strip width of eight meters (Capinera et al., 1985). Nowadays the majority of tractors in China has a small working width of less than two meters. Thus strip systems seem an appropriate solution that can make use of existing synergisms. In this case farmers can maintain most management practices, like sowing and harvesting dates of the two component crops. One point that has to be examined by agronomic research is the optimum strip width of the two components. The width of the strip has a strong impact on the availability of the growth factors nutrients, soil water and especially solar radiation. Intensive field experiments will be necessary. To tap the full potential of a system it has to be tailored to the local soil and climate conditions. Furthermore the selection of suitable cultivars of both component crops offers an increase in yield potential. As described by Lesoing and Francis (1999) inter- and intra-row spacing should additionally be optimized. To accomplish this in an efficient manner crop growth models should be employed. Models make it possible simulate various crop combinations at various locations under varying strip widths. Hence, multi-location and multi-cultivar testing can be reduced to the possible minimum. Certainly models are needed that sufficiently consider morphological differences between cultivars, as the morphology of the two component crops decides to a great extend on their resource capture potential.

Another aspect that differs strongly between the traditional row intercropping systems and mechanizable strip systems is weed infestation (Curse and Gilley, 2008). In the row system strong intra-species competition already guaranties that only very limited growth factors are available for potential weeds. When strips are getting wider weeds have a greater chance to infest the strip of the later component crop. The wider the sowing dates of the two crops are set apart the more this problem aggravates. An integrated weed management program has to be developed that considers susceptibility of one component crop against certain active substances.

What agronomists often consider insufficiently is the profitability of a cropping system. Only if the yield advantage is able to even out the extra costs of additional management measures, the system has any chance to be widely adapted. To test the economic sustainability of a certain system sensitivity analysis has to be applied using varying labor, input and output prices.

It became obvious during the inquiry that the perception of the future potential of intercropping in China differs strongly. While farmers practicing intercropping are very confident that the adoption of the system in use will increase in the future, researchers and especially extensionists are more critical. One statement was very striking and very well represents the attitude of most extension staff in the region: “In Europe or the US, they would never promote intercropping as a future cropping system”. The question whether intercropping as a traditional system can be combined with the demands of modern agriculture will be decisive. If the state extension staff has the feeling that they would miss chances for their clients, if they promote an old system, even the most promising strip-intercropping system is foredoomed to failure. Therefore it is necessary to develop an integrated research approach that includes all stakeholders involved in practice and knowledge transfer from the beginning. Bridging the gap between theory and practice in sustainability research (Knowler and Bradshaw, 2007; von Wirén-Lehr, 2001) is always an issue. Production techniques that proved successful in experiments not necessarily work out in the field. Therefore the cooperation with local extension staff and the conduction of farmer field experiments is needed.

The second pathway, the adjustment of machinery to mechanize row intercropping would help farmers significantly, as they could maintain the traditional systems. Additionally all attributed advantages of row intercropping could be maintained, from yield advantage to environmental benefits. As the design of intercropping systems vary strongly worldwide, and even on regional scale in China, there is hardly any commercial interest by agricultural engineering companies to research and develop such machinery. However, after intensive literature and internet search one research group could be found. The "Lowland crop rotation research team" at the National Agricultural Research Center for Tohoku Region in Northern Japan developed a very promising machine, called the "interseeder". It enables the sowing of wheat and soybean in a double-relay wheat-soybean row intercropping system. In spring soybean is sown in rows into the wheat crop. In autumn wheat is sown into the soybean stand. Depending on climatic growth conditions the overlay in both spring and autumn is several weeks long. The system had been of quite an importance for agricultural production in the Tohoku region until the middle of the last century. With increasing mechanization however, farmers step by step gave up the system. The newly developed seeder is a high clearance tractor which is equipped with three fertilizer and drill units. Thus three rows can be sown simultaneously (Amaha, 2006). However, seeding capacity is limited and high development and production cost didn't allow the "interseeder" to become a commercial success.

Conclusion

Most intercropping systems which are still practiced nowadays in China are prone to extinction. With steadily increasing labor costs, intercropping systems which demand a huge amount of manual labor are becoming less and less profitable. Additionally the traditional row intercropping systems can not get in line with the strongly increasing use of agricultural machinery. Research has to offer solutions to farmers, if this sustainable system should be maintained. Applying an integrative research approach is best suited to cope with all the challenges. Only systems which convince both extensionists and farmers have a potential to be successfully distributed and adapted. Only systems which are widely adapted have any potential to benefit the environment considerably. The inclusion of crop modeling techniques is a prerequisite to allow the successful adjustment of the traditional row systems to strip systems that can be mechanized. Thereby the huge variety of intercropping crop combinations and climatic regions in China can be accounted for.

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