

Agricultural Development and Mechanization in 2013 A Comparative Survey at a Global Level

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ABSTRACT:

This paper examines several rather broad questions: What are the world trend and evolution of agricultural mechanization? What are the factors driving the future demand for agricultural mechanization at global level? What would be the changes in the structure of domestic demand, imports and exports of agricultural machinery over the next 10 years? And what would be the future market penetration of selected high-tech innovative agricultural machinery? The findings of this paper are based upon a review of available industry data for agricultural mechanization and a survey targeting major Associations of Agricultural Machinery Manufacturers. The survey investigated questions related to: (i) General development tendencies likely to affect the future demand of agricultural mechanization; (ii) main field operations for the production of staple crops; (iii) Trade related to agricultural machinery – including implements, tractors and combines; (iv) the impact that selected issues (irrigation, organic production, and growth in the bio-fuel/bio-products markets) will have on the demand for agricultural mechanization; and (v) the technological trends for the sector over the next 10-20 years.

1. Challenges in Agriculture and the Role of Mechanization

In the 21st century, agriculture remains an essential sector for sustainable development but at the same time, is facing major challenges and risks. Indeed, while the natural resources that sustain agriculture are becoming increasingly scarce, degraded, and vulnerable to the effects of climate change, the world's demand for food is expected to double within the next 50 years. In several poor countries, agriculture accounts for at least 40% of GDP and 80% of employment. And about 70 percent of the world's poor live in rural areas and most depend on agriculture for their livelihoods (WDR, 2008).

Furthermore, while the agricultural sector has been basically successful in meeting the world's effective demand for food, still more than 800 million people continue to be food insecure, and the sector has left a sizable environmental footprint. To meet the projected demand for food under current circumstances (especially rising world population), agricultural production needs to increase by 60% over the next four decades. This means that every year 1 Bnt of cereals and 200 Mt of meat have to be produced additionally compared with 2005/07 levels (OECD-FAO Agricultural Outlook 2012). Added to this, the economic growth of emerging markets in Asia, Middle East and Latin America leads to higher living standards in combination with a change in diet (Msangi and Rosegrant, 2012). People adopt a western lifestyle which goes along with a higher consumption of meat and dairy products. Because the conversion efficiency of plant into animal matter is about 10%, a meat-based diet requires significantly more resources than a vegetarian diet (Godfray et al., 2010). As a consequence, rising feed requirement puts pressure on the agricultural markets as well as the expanding biofuel production, which is mainly based on food crops such as sugarcane, corn and vegetable oil. The production of ethanol and biodiesel is predicted to rise by 5% p. a. over the next ten years (OECD-FAO Agricultural Outlook 2012) and already pushed up world food prices.

Considering these facts, agricultural production underlies an enormous growth requirement, even though the scope for arable land expansion is limited. The existing world arable land of 1.548 Mha is projected to increase by only 69 Mha by 2050. The situation gets even more critical with regard to water scarcity and land degradation (more than to 25%) in many countries. Also, the impact of climate change is expected to be important with little capacity to cope, especially in Sub-Saharan Africa. Therefore, managing the aggregate response of agriculture to rising challenges and risks will require sound policies and sustained investments, not business as usual (Rosegrant and others 2007).

In the last decades, the total factor productivity¹ (TFP) in agriculture increased in developed countries by rates exceeding 2%. Such increases in TFP tend to be limited in countries with high levels of productivity, but significant growth rates are still observed in transition countries of Central and Eastern Europe as well as in emerging markets such as Brazil and China. Figures registered for most least-developed countries remains low, although some increased their TFP by 2-3 % p.a. in the 2000s. Overall, predictions indicate that the output per capita will still rise by 0,7 % every year and production gains will actually exceed the population growth, although the rise of the global agricultural production will slow down from 2,2 % p. a. in the last decade to 1,7 % p. a. in the next ten years (Alston et al., 2010 / OECD-FAO Agricultural Outlook 2012).

The increase of the world agricultural output in the past and in the future depends on various factors. Land productivity is improved by the use of fertilizer, herbicides, plant and animal breeding, the extension of irrigated agricultural area and the optimization of management practices. Whereas the increase of land productivity seems to reduce speed in many parts of the world, labor productivity gains in importance as labor continues to move out of the sector. Its constant increase mainly goes back to the ongoing mechanization in agriculture especially in the developed, but also in transition countries (Alston et al., 2010).

Mechanization is a key factor for agricultural development and farmers' wellbeing. Not only it helped improving labor productivity up to 500 times in comparison to agriculture without motorization and without chemical application (Mazoyer, 2001), mechanization provides also the power to ensure that agricultural operations for the soil, the plants and the animals are done precisely in time and with the highest efficiency. Thereby the quality of agricultural products specified by their ingredients, freshness, maturity and shelf life are improved, leading to higher prices at the market. Furthermore, with the recent development in terms of precision farming technologies, side effects for the environment due to fertilizers and chemicals can be reduced substantially. This also means that smaller amounts of fertilizers and chemicals are applied and production costs can be reduced.

However, it has to be considered that the level of mechanization and labor productivity in any given area is influenced by several variables and can change considerably from a region to the other. Important variables influencing these changes are: (i) The natural conditions such as rainfall, temperature, climate change, land availability/degradation, and water availability; (ii) The economic status, including technical progress, economic development, energy supply and oil prices, and the global agricultural trade; (iii) The demographic conditions in a region/country with factors such as the population growth, aging population in rural areas, urbanization and change in diet, and quality requirements of consumers; and (iv) The political conditions which may be represented by elements such as food security/safety goals, education/training of farm operators, research, subsidies and farm structure development (Böttinger et al., 2010).

Technology and other innovative improvements, in particular agricultural mechanization, will have to play an important role in working towards creating a food secure world. The results presented in this paper are updating those concluded from a previous survey carried-out in 2009 which analyzed some of the emerging trends and medium term predictions for agricultural mechanization in a number of countries/regions of the world (Böttinger et al., 2010). These are based on a new survey conducted in 2013 (see Section 2 below).

2. Methodological Approach

The objectives of this paper are to; (i) Examine the recent trend and evolution of agricultural mechanization development; (ii) Identify some of the factors driving the future demand for agricultural mechanization at global level; (iii) Analyze the changes in the structure of domestic demand, imports and exports over the next 10 years; and (iv) Predict the future market penetration of selected high-tech innovative agricultural machinery.

In this respect, a detailed questionnaire was sent out to leading representatives and associations of the agricultural machinery manufacturing sector. The survey investigated issues related to²: (i) General development tendencies likely to affect the future demand of agricultural mechanization; (ii) main field operations for the production of staple crops; (iii) Trade related to agricultural machinery – including implements, tractors and combines; (iv) the impact that selected issues (irrigation, organic production, and growth in the bio-fuel/bio-products markets) will have on the demand for agricultural mechanization; and (v) the technological trends for the sector over the next 10-20 years.

¹ The total factor productivity is defined as total outputs over total inputs and is used to express the competitiveness and the efficiency of an industry.

² Under this framework, the underlying assumption is that responses received to the survey questions would provide a clear and reliable indication of the evolution and trends of the technology, markets, and production practices related to the targeted sector.

The authors of this study grouped and collected information from the following regions: (i) European Union (EU); (ii) Commonwealth of Independent States (CIS); (iii) Japan; (iv) Asia; (v) Sub-Saharan Africa; (vi) North Africa/Middle East; (vii) North America; (viii) Latin America; and (viiii) Australia. The regions were differentiated taking into consideration their homogeneity and the location of the major manufacturing industry/associations. Other criteria such as the economic development stage (developing, transformational status, developed), natural and climate conditions and status of agricultural mechanization, were also considered. Figure 1 shows the Nations of the World and indicates the main geographical regions differentiated in this study.

Figure 1: Main focus of survey per geographical region



Map Source: University of Texas Library

36 agricultural machinery manufacturers associations and institutions from the indicated regions were contacted and included in the survey. Fourteen completed questionnaires were returned (see details in Table 1)³.

Table 1: Associations and/or institutions surveyed

Country	Association and/or Institution	Region
Germany	VDMA – Verband Deutscher Maschinen- und Anlagenbaue	European Union
Italy	UNACOMA – Unione Nazionale Costruttori Macchine per l’Agricoltura	
France	AXEMA – Union des Industriels de l’Agro-Equipment	
Finland	Federation of Finnish Technology Industries	
USA	AEM – Association of Equipment Manufacturers	North America
Japan	JFMMA – Japan Farm Machinery Manufacturer’s Association	Japan
China	CAAMM – China Association of Agricultural Machinery Manufacturers	Asia
India	FICCI – Federation of Indian Chambers of Commerce and Industry	
	IARI – Indian Agricultural Research Institute CIAE - Central Institute of Agricultural Engineering	
Morocco	Institut Agronomique et Veterinaire Hassan II	North Africa/ Middle East
Cameroon	The University of Dschang	Sub-Saharan Africa
Botswana	Botswana College of Agriculture	
South Africa	SAAMA – South African Agricultural Machinery Association	

Source: Own data

³ For comparison, the participants of the survey conducted in 2010 were associations from Germany, Finland, the Netherlands, Italy, the USA, India, Russia and Brazil.

3. Basic Facts about the Countries Observed

Table 2 summarizes some basic socio-economic data for the surveyed countries. The demographic situation in these countries differs highly in terms of population (number of people, percentage of rural/urban and growth). In the EU, the US and Japan the population growth rate is quite low and reaches barely half of the population growth rate of African countries. In Cameroon the growth of population is even four times higher than in France and Finland, which are marked by the highest growth rates of European countries within the sample. The representatives of the Asian region, China and India, are both the two most populous countries in the world and those with the highest share of rural population. But, meanwhile the population growth rate in China is similar to western countries; the Indian population grows three times faster.

Looking at the economic situation, the EU, the USA and Japan are considered developed countries due to their very high GDPs in relation to their population and their high income and welfare levels. Other countries such as China and India are seeing in recent years considerable GDP growth levels and can be categorized as emerging economies. Except for South-Africa, most other African countries are still developing economies.

Table 2: Demographic and economic situation in the countries observed

Country	Population [m]	Rural population [% of pop.]	Population growth [%]	GDP [bil. \$]	GDP growth [%]	Exports [% of GDP]	Income level*
Year	2012	2012	2011	2012	2012	2011	2013
Germany	82	26	0,0	3399	0,7	50,2	↑
Italy	61	17	0,4	2013	- 2,4	28,8	↑
France	66	14	0,5	2612	0,0	26,9	↑
Finland	5	16	0,5	250	- 0,2	40,8	↑
USA	314	17	0,7	15684	2,2	14,0	↑
Japan	128	8	0,3	5959	1,9	15,1	↑
China	1351	48	0,5	8227	7,8	31,4	↗
India	1237	68	1,4	1841	3,2	23,9	↘
Morocco	33	43	1,0	96	2,7	34,9	↘
Cameroon	22	47	2,2	24	4,7	30,6	↘
Botswana	2	38	1,2	14	6,1	42,3	↗
South Africa	51	38	1,2	384	2,5	29,3	↗

*↓ = Low income, \$1,035 or less; ↘ = Lower middle income, \$1,036–4,085; ↗ = Upper middle income, \$4,086–12,615; ↑ = High income, \$12,616 or more. Data: World Bank (2013).

Table 3: Selected data for the agricultural sector in the countries observed

Country	Agricultural land [1000 sq. km]	Cereal yield [kg/hectare]	Agriculture, value added [% of GDP]	Agriculture value added per worker [US \$]	Employment in agriculture [% of total employment]	Tractors per 100 sq. km of arable land
Year	2011	2011	2010	2010	2010	2000
Germany	167	6460,7	0,9	32087	1,6	838
Italy	139	5681,8	1,9	41267	3,8	1938
France	291	6859,1	-	-	2,9	685
Finland	23	3533,6	2,9	60842	4,4	781
USA	4113	6818,0	1,2	57194	1,6	257
Japan	46	4910,7	1,2	39284	3,7	4532
China	5191	5705,5	10,1	681	36,7	82
India	1798	2883,3	18,0	641	51,1	129
Morocco	301	1407,3	15,4	3780	40,2	-
Cameroon	96	1768,1	-	-	53,3	-
Botswana	259	393,3	-	-	-	77
South Africa	964	4024,0	2,6	5510	4,9	49

Data: World Bank (2013)

As expected, agricultural data show that the sector's importance in relation to the overall economy is very low in developed countries (see Table 3). In Finland agriculture represents 2,9% - the biggest share of GDP of all countries surveyed in the EU. In the USA and in Japan agriculture contributes only 1,2% to the GDP. In relation to that, the share of employees engaged in agriculture is quite low and varies within the sample from 1,6% in Germany to 4,4 % in Finland. However, the value added per worker is higher than in emerging and in developing countries. For example, one agricultural worker in Finland generated 60.842 US\$ in 2010, whereas in India, where over 50% of all employees are engaged in agriculture, a worker only generated 641 US\$.

The data related to the number of tractors per arable land is shown in Table 3. Taking into consideration that complete data is only available for the year 2000 and the situation might have improved over time, we can still see that in Africa and Asia there is a significantly lower use of tractors than in developed countries. Because the number of tractors used in a region always depends on farm structure, field sizes and the kind of agricultural production, there are also large differences in tractor use between European countries, Japan and the US.

4. Survey Results

4.1 Factors driving the Future Demand for Agricultural Mechanization

The first part of the survey focused on analyzing selected factors driving the future demand for agricultural mechanization. The responses received are summarized in Table 4. The latter gives a cross overview comparison of the direction and the magnitude each factor as it influences agricultural mechanization in a given country.

- Overall natural conditions seem to have relatively low impact on future demand for agricultural mechanization and the direction of the impact fairly varies. However, water availability might be a crucial point in the future. Almost all experts who contributed to the survey and in particular those of southern countries rank the importance of this factor as high.
- Factors concerning the economic conditions were identified as rather uncertain. While the technical progress, the economic welfare development and the internationalization of agricultural trade have positive impacts on the demand (almost all responses), the ongoing economic crisis will reduce the demand for mechanization in agriculture in the next ten years. Furthermore, the expected effects of oil price and energy supply differ between the countries and presumably depend on the individual structure of demand and supply.
- Looking at the influence of demographic factors, it is important to differentiate between the development stages of the various countries surveyed. In developing countries and emerging economies, the mechanization level is relatively low and there is an existing need for further mechanization. The latter will become more relevant if people move out of the agricultural labor (likely to be expected). Developed countries are subject to a different scenario which can be categorized as an over-mechanization. In this case, any labor force losses can be compensated rather swiftly⁴.
- Almost every demographic factor investigated in the survey promotes in a significant way agricultural mechanization in developing and emerging countries. The same conclusion is only noted in the case of developed countries with regard to population growth and quality requirements of consumers. Factors such as the aging population in rural areas or urbanization affect the demand for agricultural mechanization mostly in a negative way in the developed countries.
- Overall the most positive signals for a rising demand of agricultural mechanization are governments based. Agriculture has always been a sector subject to a special protection through supportive policies for achieving food security goals and developing rural areas. Farmers' protection, e. g. by granting subsidies, leads to higher earnings, lower risks and therefore to a higher willingness to invest in the sector. More recent issues like bio-fuel production are also supported by governments. These also lead to a rising demand for agro-commodities and higher outputs in agriculture.
- Research, education and efficient farm structures are also found to be important determinants for the demand for agricultural mechanization. They seem to develop in a positive way all over the world.

In comparison to the 2010 survey results, the demographic and political factors are rated higher. At that time economic factors were the primary drivers shaping the demand and adoption decisions of agricultural producers. Most surveyed manufacturer associations saw low/medium impacts from the natural, political, and the demographic drivers. A reason for the general shift in opinion could be that the influence of demographic and political factors has increased. On the other hand, the sample of 2010 didn't cover any African countries and only one Asian country (India). The share of Asian and African countries in the current sample is higher. In fact, the results of the 2013 survey show that political as well as demographic factors seem to be more important for the surveyed Asian and African countries than they are for the developed countries (EU, USA and Japan).

⁴ The results of the survey underline this assumption.

Table 4: Factors driving the future demand for agricultural mechanization

	Germany	Italy	France	Finland	USA	Japan	China	India	Morocco	Cameroon	Botswana	South Africa
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a) Natural conditions

Rainfall	+/- 0	+/- 4	+/- 3	+2	+/- 1	+/- 3	+/- 1	+/- 2	- 3		+/- 3	+/- 3
Temperature	+/- 1	+/- 3	+/- 3	+1	+/- 1	+/- 3	+/- 1	+2	- 1		- 3	+/- 2
Climate change	+/- 1	- 3	- 2	+1	+/- 1	+/- 3	+/- 1	+3	+/- 2	- 3	- 3	+/- 2
Land	+/- 2	+/- 2	+/- 1	+/- 0	+/- 1	+/- 2	+/- 1	- 2	- 3		+/- 0	+/- 1
Water availability	+ 1	+/- 3	+ 2	+ 3	+/- 3	+/- 3	+/- 3	+ 4	- 4	+ 4	+/- 4	+/- 2

b) Economic conditions

Technical progress	+ 4	+ 4	+ 4	+ 1	+ 2	+ 3	+ 4	+ 3	+ 4	+ 3	+/- 3	+ 3
Economic welfare development	+ 1	+/- 3	+ 2	+ 1	+/- 1	+/- 1	+ 4	+ 3	+ 3	+	+/- 3	+ 2
Oil price	+/- 3	+/- 3	+/- 3	- 2	- 1	+ 3	- 2	+/- 3	- 4	-	+/- 3	+ 2
Economic crises	- 0	- 4	- 3	- 2	- 1	+/-	- 3	- 2	- 3	-	- 3	+/- 2
Energy supply	+/- 3	+/- 3	- 2	+ 3	- 3	+/- 2	+/- 4	+ 4	+ 3	-	+/- 3	+/- 2
Internationalization of agr. trade	+ 4	+ 4	+/- 2	+/- 2	+ 1	+ 3	+/- 3	+ 3	+ 3	+	+/- 4	+/- 2

c) Demographic conditions

Population growth	+ 0	+ 4	+ 3	+ 1	+/- 3	- 3	+/- 1	+ 2	+ 4	+ 4	+/- 3	+ 3
Aging population in rural areas	+ 1	- 3	- 2	- 1	- 2	+ 3	+/- 3	+ 3	+ 3	+ 4	+/- 4	+ 2
Change in diet	+/- 1	+ 3	+/- 3	+/- 1	+ 1	- 1	+/- 2	+ 2	+ 3	+ 3	+ 3	+ 3
Urbanisation	+/- 0	- 3	+/- 2	+/- 1	- 1	+ 2	+ 3	+ 3	+ 4	+ 4	+ 3	+ 2
Quality requirements of cons.	+ 2	+ 3	+ 3	+/- 2	+ 2	+/- 2	+/- 1	+ 3	+ 3	+ 3	+ 3	+ 2

d) Political conditions

Food security goals	+ 0	+ 4	+ 2	+/- 1	+ 2	+/- 1	+ 4	+ 3	+ 4	+ 3	+/- 3	+ 2
Education of farm operators	+ 2	+ 3	+ 3	+ 2	+ 2	+/- 2	+ 2	+ 4	+ 4	+ 4	+ 3	+ 2
Research	+ 2	+ 3	+ 3	+ 2	+ 2	+ 2	+/- 1	+ 3	+ 3	+ 3	+/- 4	- 3
Subsidies	+ 3	+ 4	+/- 3	+/- 3	+ 2	+ 4	+ 4	+ 4	+ 4	+ 4	+ 4	- 3
Farm structure development	+ 3	+ 3	+ 3	+/- 3	+ 1	+ 4	+/- 3	+ 3	+ 3	+ 4	+/- 3	+ 2
Biofuel production	+ 1	+ 3	+/- 2	+ 3	+ 3	+/- 1	+ 3	+ 3	+ 3	+ 3	+/- 3	+ 3

Legend

Direction of impact		Magnitude of impact	
	[+] positive	[0] none	[3] significant
	[-] negative	[1] little	[4] strong
	[+/-] both	[2] moderate	

Source: Own survey

4.2 Levels of Agricultural Mechanization Today and in the Future

To illustrate the existing and potential future profile of agricultural mechanization in a given country/region, the associations and institutions surveyed were requested: (i) to provide an informed opinion about the current mechanization status and (ii) to forecast what would be the predominant mechanization type and/or level in their country in the next 10-20 years. To help in this process, they were provided with twelve development levels/stages of typical mechanization schemes to select from (Table 5). Although such predictions may be seen as highly subjective, it was felt that by soliciting responses from the surveyed associations and institutions' focal points, a sensible degree of credibility and reliability can be achieved. Figures 2 to 4 illustrate the findings of the survey.

As expected and in line with the results of the survey conducted in 2010, developed countries are characterized by high mechanization levels. Germany is already showing a moderate share of autonomous vehicles (level 11). Other developed countries are in the process of reaching this stage- the USA in 10 years and Italy, France, Finland, and Japan in 20 years. At the moment their development stages range from level 9 to 10. In the US the breakthrough of autonomous vehicles is in part inhibited due to safety concerns, but will probably happen in the next years.

Table 5: Twelve levels of agricultural mechanization

Level	Farm power characteristics	hand	Draught animal	tractors	Nomin. speeds (km/h)		No. of speeds	Shift	PTO speeds rpm
					forw.	rev.	forw./rew.		
1	Predominantly hand power	> 80	<= 20	<= 5					
2	Significant use of draught animal power	46 – 80	21 – 39	<= 10					
3	Significant use of tractors	15 – 45	>= 40	<= 19					
4	Tractors predominant	20 – 50	15 – 30	20 - 49					
5	Fully motorized technology level I	<= 25	<= 25	50 - 75					
6	Fully motorized technology level II	<= 10	<= 10	> 75	2 – 20 (25)	3 - 8	6/2 – 8/2	SG, CS	540
7	Fully motorized technology level III	“	“	“	2 - 30	3 - 10	8/4 – 12/4	CS, SS	540/(1000)
8	Fully motorized technology level IV	“	“	“	(0,5) 2 – 30 (40)	3 - 15	12/4 – 16/8	SS, HL	540/1000
9	Fully motorized technology level V	“	“	“	(0,3) 2 – 40 (50)	2 - 20	16/12 – 36/36	SS, PPS, FPS	540/1000
10	Fully motorized technology level VI	“	“	“	0 – 50 (60)	0 - 25	∞	autom.	(750/1250)
11	Moderate share of autonomous vehicles								
12	Significant share of autonomous vehicles								

Source: Clarke et al. (2002) / Renius (2005), modified.

In other parts of the world rapid developments of agricultural mechanization are forecasted. For instance mechanization is predicted to develop fast in Morocco - starting from level 5 currently and reaching level 8 in the next twenty years. In Cameroon, agricultural mechanization was described as being at level 1. In this country, agriculture is dominated by small-scale farmers (85%) which principally use hand tools (85%). Tractors are mainly used in large commercial farms, which represent only a share of 4%. This situation is however expected to improve in the next 10 to 20 years to reach level 4 (Tractors predominant) due the need of increasing production as well as the expected rural exodus to cities. Finally, in South-Africa the mechanization level of commercial agriculture is set to be at level 8 and is predicted to raise about one level every ten years.

In Asia the Chinese path of development of mechanization seems to be much quicker than in India. In China the current overall mechanization is assessed at level 7 and is predicted to reach level 10 in the next 20 years. In India an improvement from level 4 to level 6 is expected for the same time period.

Important to note that there are significant interregional differences within India (climates and natural resources). In the north of India the surveyed association reported a current mechanization level of 5. In the East and North-East regions of India, the figures reported were limited to level 3. Finally, in comparison to the previous survey of 2010, the current prediction for India is quite pessimistic. At that time the achievement of level 9 was assumed as realistic for the next twenty years.

Figure 2: Agricultural mechanization - Current status

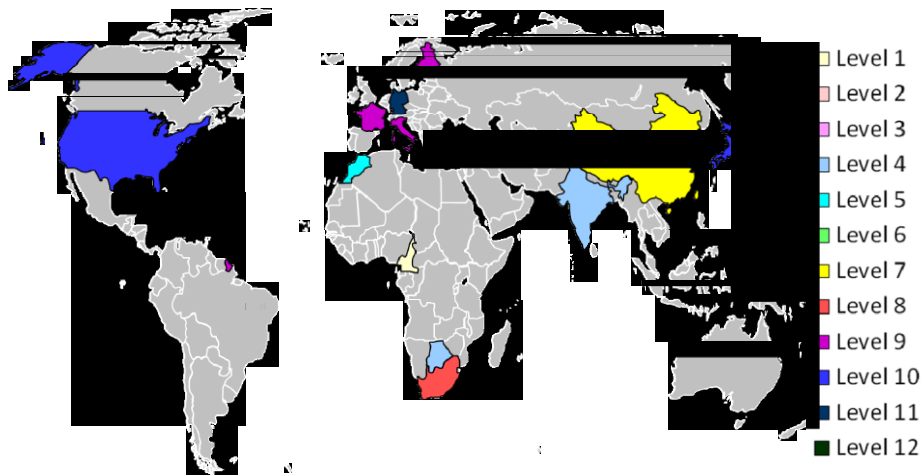


Figure 3: Agricultural mechanization – 10 years prediction

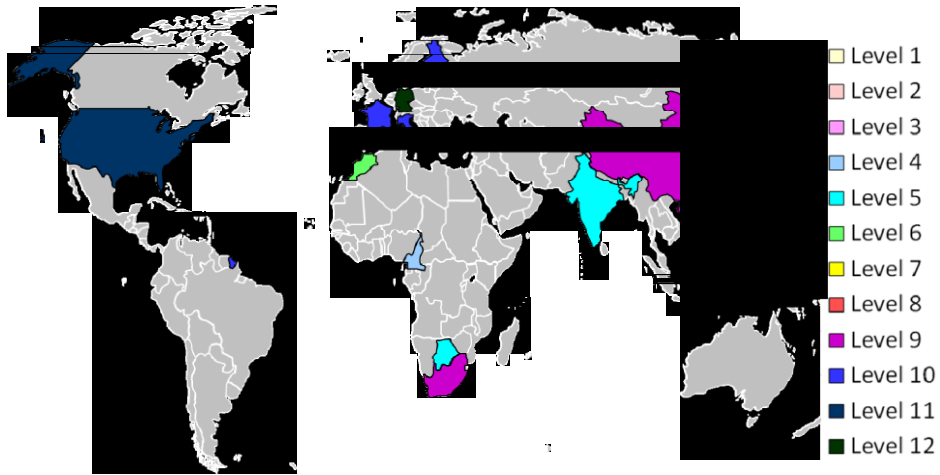
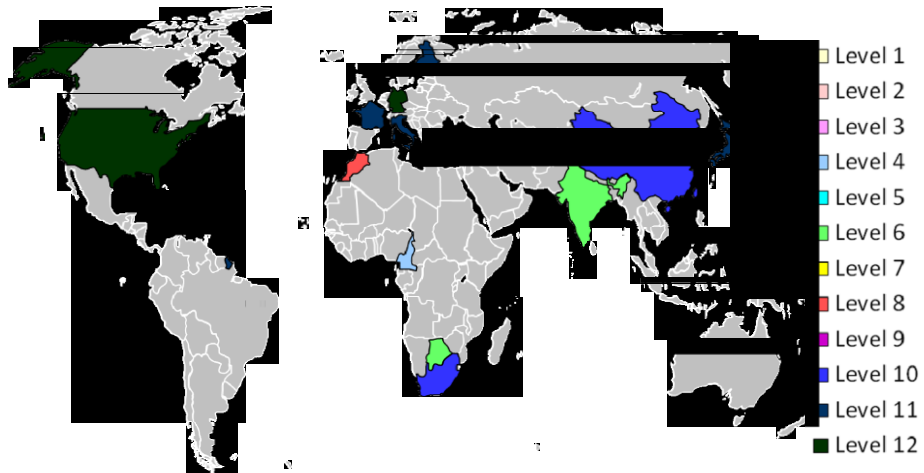


Figure 4: Agricultural mechanization – 20 years prediction



Source: Own survey

4.3 Progress in the Production of Staple Crops

To identify weaknesses in the production process of crops and to find starting points for further improvements, the surveyed associations and institutions were asked to select the most important staple crop in their region and then to assess the relative rate of progress in its production in relation to the average development worldwide. Accordingly, some field operations were evaluated with respect to their further need for mechanization development. Tables 6 and 7 summarize the corresponding survey results.

Wheat was identified as the most important staple crop for Germany, France, China, India and Morocco. The relative progress in production of wheat was set to be on a worldwide average in China and Morocco, whereas it was set as above average in Germany, France and India. These observations lead to the conclusions that in Germany and France only minor mechanization improvements are required across the wheat production chain. In contrast to that in China, India and Morocco a significant to strong need for further improvements is identified in various fields of operation.

Table 6: Progress in the production of staple crops - Wheat

	Germany	France	China	India	Morocco
Most important staple crop	Wheat	Wheat	Wheat	Wheat	Wheat
Rate of progress in production	↗	↗	→	↗	→

Need for further mechanization development:

Tillage	0	1	2	3	2
Seedbed preparation	0	1	3	4	2
Sow	0	1	1	4	2
Replant	0	1	1	0	3
Irrigation	2	1	3	3	4
Plant protection (mech.)	1	1	1	2	3
Plant protection (chem.)	0	1	3	2	3
Manure application	0	1	1	2	4
Fertilizer application	0	1	2	3	2
Harvest	0	1	3	4	4
Transport	0	1	2	3	1
Storage	0	1	3	4	3
Processing	0	1	3	/	3

Legend

Speed of progress	Need for further mechanization development	
[↑] clearly above worldwide average	[0] none	[/] not relevant
[↗] above worldwide average	[1] little	[-] not specified
[→] worldwide average	[2] moderate	
[↘] below worldwide average	[3] significant	
[↓] clearly below worldwide average	[4] strong	

Source: Own survey

Maize was selected as the main staple crop for Italy and the US as well as in the Southern African region represented by Cameroon, Botswana and South Africa (Table 7). In the US the speed of progress was categorized as far above worldwide average, with little or moderate need for further mechanization development in each field operation. The respondents suggested further optimization of the production process by adopting the use of drones and robotics. A special reference was made to the use of minimum- or no-till seeding technology in combination with precision farming.

Data obtained from Italy and Botswana classified the progress in maize production as similar to the current worldwide average, but with a clear lack in mechanization development. Critical points were observed for both countries, including irrigation as well as tillage and seedbed preparation. In addition, Botswana's respondent reported a special need for further mechanization of sowing operations.

Cameroon reported a status of below worldwide average with a strong need for further improvements in several mechanized operations (see Table 7). For this country, as well as for South-Africa, a special reference was made also to encourage the use of minimum tillage equipment and direct seeding.

The respondents from India were the only ones who reported three staple crops as the most important in their country (wheat, rice and sugarcane). For both crops (rice and sugarcane; Table 8) the rate of progress was classified as being above world average. But while India seems to make concrete progress, there are strong lacks in mechanization across nearly all field operations (especially as far as harvesting and post-harvest operations are concerned). A main problem stated is the large number of small fields that are not accessible for combine harvesters and therefore there is a special demand for small combines. Also, the transplanting of rice

could be improved by the use of small self-propelled rice transplanters. For sugarcane production it was suggested that more tractor drawn planters and harvesters should be introduced.

For the case of Japan, rice was reported as the main staple food (Table 8). The progress in production of this crop is determined as far above world average, but with still improvements to be made especially in replanting, harvesting and processing.

For Finland barley was reported as the main staple crop (Table 8). In this country mechanization progress is relatively high with only limited need for further improvement all across the production process (except for replanting, plant protection and irrigation). Improvements in manure application and chemical plant protection were also mentioned as a mean to reduce the pollution of the Baltic Sea and the environment in general.

Table 7: Progress in the production of staple crops – Maize

	Italy	USA	Cameroon	Botswana	South Africa
Most important staple crop	Maize	Maize	Maize	Maize	Maize
Speed of progress in production	→	↑	↓	→	-
Need for further mechanization development:					
Tillage	3	1	4	3	3
Seedbed preparation	3	1	4	3	3
Sow	-	1	4	4	3
Replant	-	1	1	2	-
Irrigation	3	1	3	4	3
Plant protection (mech.)	2	1	3	3	3
Plant protection (chem.)	2	1	3	3	3
Manure application	2	2	1	3	1
Fertilizer application	2	1	4	3	3
Harvest	2	1	1	3	3
Transport	2	2	2	3	3
Storage	2	1	4	3	3
Processing	2	1	3	3	3

Table 8: Progress in the production of staple crops – Barley, Rice, Sugarcane

	Finland	Japan	India	India
Most important staple crop	Barley	Rice	Rice	Sugarcane
Speed of progress in production	↗	↑	↗	↗
Need for further mechanization development:				
Tillage	2	1	3	3
Seedbed preparation	2	3	3	3
Sow	3	2	2	4
Replant	1	4	4	/
Irrigation	1	3	4	4
Plant protection (mech.)	1	3	4	4
Plant protection (chem.)	3	2	3	3
Manure application	3	3	2	3
Fertilizer application	3	3	3	3
Harvest	2	4	4	4
Transport	2	2	2	3
Storage	2	3	4	/
Processing	3	4	4	3

<u>Speed of progress</u>	<u>Need for further mechanization development</u>	
[↑] clearly above worldwide average	[0] none	[/] not relevant
[↗] above worldwide average	[1] little	[-] not specified
[→] worldwide average	[2] moderate	
[↘] below worldwide average	[3] significant	
[↓] clearly below worldwide average	[4] strong	

Source: Own survey

4.4 Development of Domestic Demand, Exports and Imports

Another area of interest has been the outlook that respondents had concerning possible changes in the structure of domestic demand, imports and exports over the next 10 years. Tables 9 to 11 indicate the findings related to the twelve sample groups.

Africa and Asian countries are growing markets with an increasing domestic demand for nearly every kind of machinery and implement. This underlines the growing importance of agriculture in these regions. For the particular cases of India and China where a significant economic growth has been registered in the last decade, the emerging domestic industry seems to be able to satisfy the growing demand for agricultural machinery. Hardly any significant import increase was predicted, but rather both countries are predicted to become major export players. In Africa, the situation is different with limited industry established and imports will probably rise in a significant way.

The demand structure in the other countries surveyed (developed countries) is variable and highly depending on the existing situation within each country. However, there is a convergence in terms of: (i) the domestic industry need to focus on export markets to growth; and (ii) positive expectations for the development of agricultural machinery exports. Further details are provided in the tables below.

Table 9: Domestic demand over the next ten years

	Germany	Italy	France	Finland	USA	Japan	China	India	Morocco	Cameroon	Botswana	South Africa
Small size tractors (<= 40 hp)	→	↗	↗	↗	↗	↘	↗	↗	→	↗	↗	→
Medium size tractors (<= 100 hp)	→	↗	↗	↘	↗	↗	→	↗	↑	↗	↗	↗
Big size tractors (> 100 hp)	↗	↗	↗	↗	↗	↗	↑	/	↗	↗	↗	↗
Spare parts for tractors	→	↗	↗	→	↗	↗	↗	↗	↑	↑	↑	↗
Self propelling combines	→	↗	→	↘	↗	↗	→	↗	↗	↗	↗	↗
Forage harvesters	→	↗	→	→	↗	→	↑	↗	↗	→	↗	↗
Reapers	→	↗	→	→	/	/	→	↗	↗	↗	↗	↗
Threshers	/	↗	→	/	/	↘	↘	↗	↗	↑	↗	↗
Irrigation systems	→	↗	↗	↘	↑	↘	↗	↗	↑	↗	↑	↗
Diesel engines	→	↗	↗	↘	↗	↘	↗	↗	↑	↗	↑	↗
Power tillers	→	↗	→	→	→	↘	→	↗	↑	↗	↑	↗
Food processing technique	→	↗	→	→	↗	/	↗	↑	↑	↗	↗	↗
Spare parts in general	→	↗	↗	↗	↗	↘	→	↗	↑	↗	↑	↗
Hand implements	/	/	→	↘	↘	/	→	↗	→	↑	↑	↗
Draught animal implements	/	/	→	/	/	/	/	→	/	↗	↑	↗
Soil preparation	→	-	↗	↗	↗	→	→	↗	↗	↗	↑	↗
Seeding	→	-	↗	↗	↗	→	→	↗	↗	↗	↑	↗
Plant protection	→	-	↗	↗	↗	→	↗	↗	↗	↗	↑	↗

Legend

[↑] >= 10% annual growth rate	[↘] -10% to 0% annual growth rate	[-] not specified
[↗] 0% to 10% annual growth rate	[↓] <= -10% annual growth rate	
[→] +/- 0% annual growth rate	[/] not relevant	

Source: Own data

Table 10: Import development in the next ten years

	Germany	Italy	France	Finland	USA	Japan	China	India	Morocco	Cameroon	Botswana	South-Africa
Small size tractors (= < 40 hp)	↗	↗	↗	↗	↗	↗	↘	→	→	↗	↗	→
Medium size tractors (= < 100 hp)	↗	↘	↗	↘	↗	↗	↘	→	↗	↗	↗	↗
Big size tractors (> 100 hp)	↗	↘	↗	→	→	↗	→	/	↗	↗	↗	↗
Spare parts for tractors	→	↗	↗	→	↗	↗	→	→	↗	↗	↗	↗
Self propelling combines	→	↘	→	↘	→	→	→	→	↗	↗	↗	↗
Forage harvesters	→	↘	→	↗	→	→	↗	-	↗	↗	↗	↗
Reapers	→	↘	→	↘	/	/	→	-	↗	↗	↗	↗
Threshers	/	↘	→	/	/	/	→	-	↗	↗	↗	↗
Irrigation systems	→	↘	→	↘	→	→	↗	-	↗	↗	↗	↗
Diesel engines	→	↗	↗	↘	→	→	→	-	↗	↗	↗	↗
Power tillers	→	↘	→	↘	→	↘	→	↗	↗	↗	↗	↗
Food processing technique	→	↘	→	→	↗	/	→	↗	↗	↗	↗	↗
Spare parts in general	→	↘	↗	↗	→	↗	→	-	↗	↗	↗	↗
Hand implements	/	/	→	↘	↗	/	/	→	→	↗	↗	→
Draught animal implements	/	/	→	/	-	/	/	→	/	↗	↗	→
Soil preparation	→	-	↗	→	↗	/	→	→	↗	↗	↗	↗
Seeding	→	-	↗	↗	↗	→	→	→	↗	↗	↗	↗
Plant protection	→	-	-	↗	↗	→	↗	→	↗	↗	↗	↗

Table 11: Export development over the next ten years

	Germany	Italy	France	Finland	USA	Japan	China	India	Morocco	Cameroon	Botswana	South Africa
Small size tractors (= < 40 hp)	→	↘	↗	/	↗	↗	↗	↗	/	/	→	/
Medium size tractors (= < 100 hp)	→	↗	↗	→	↗	→	↗	↗	/	/	→	/
Big size tractors (> 100 hp)	↗	↗	↗	↗	↗	→	↗	/	/	/	→	/
Spare parts for tractors	→	↗	↗	→	↗	→	↗	↗	/	/	→	/
Self propelling combines	↗	↗	→	↗	↗	↘	↗	↗	/	/	→	/
Forage harvesters	↗	↗	→	→	↗	→	→	↗	/	/	→	/
Reapers	→	↗	→	→	/	/	→	-	/	/	→	/
Threshers	/	↗	→	/	/	→	→	-	/	↗	→	↗
Irrigation systems	→	↗	↗	→	↗	→	→	↗	/	→	→	↗
Diesel engines	→	↗	↗	↗	↗	↗	→	↗	/	-	→	/
Power tillers	→	↗	↗	/	↗	↗	→	-	/	-	→	/
Food processing technique	↗	↗	↗	→	↗	/	→	↗	/	↗	→	↗
Spare parts in general	↗	↗	↗	→	↗	↗	→	↗	/	/	→	/
Hand implements	/	/	↗	→	↘	/	→	↗	/	↗	→	↗
Draught animal implements	/	/	↗	/	/	/	/	↗	/	↗	→	↗
Soil preparation	↗	-	↗	↗	↗	/	→	↗	/	→	→	↗
Seeding	↗	-	↗	→	↗	→	→	↗	/	→	→	↗
Plant protection	↗	-	↗	→	↗	→	↗	↗	/	→	→	/

Legend

[↑] >= 10% annual growth rate	[↘] -10% to 0 % annual growth rate	[-] not specified
[↗] 0% to 10% annual growth rate	[↘] <= -10% annual growth rate	
[→] +/- 0% annual growth rate	[/] not relevant	

Source: Own data

4.5 Predicted evolution of selected agriculture production issues

The current and future importance of selected issues in agricultural production were also investigated as part of this survey. These were irrigation, conservation agriculture, organic farming, bio-energy production and cooperative machinery use. They were expressed in terms of share of “total cultivated area” and also percentage distribution between small and large farms. The corresponding results are shown in tables 12 and 13 below.

Analyzing the results related to irrigation, Africa presents the lowest current percentage of irrigated land in comparison to other countries observed. The main reasons are related to a low development of the African agricultural sector and the associated limited investments in irrigation. On the contrary, other investigated countries in Asia, the US and Italy show that more than one third of the cultivated land is irrigated.

Overall the percentage of irrigated land will strongly increase in every surveyed country over the next ten years. This will be in particular the case in Africa where most respondents expect an increase of more than double of the current status. China is also predicting an important increase with an expansion of irrigated land from 30 to 80% in the next 10 years.

Conservation agriculture plays an important role in Finland (status: 30 % of cultivated area), China (30 %) and Cameroon (50 %), whereas a strong expansion to 90 % in Finland and to 70% in China is expected in future. Overall conservation agriculture will gain in importance across the surveyed countries. Only in the USA a slight decrease from 28 % to 25 % is predicted.

Table12: Selected issues of agriculture production: Share of total cultivated area

		Italy		Finland		France		USA		China		India	
		status	10 years	status	10 years	status	10 years	status	10 years	status	10 years	status	10 years
Irrigation	<i>overall share [%]</i>	37	50	5	6	6	10	28	35	30	80	35	40
	small scale farms [%]	-	-	80	80	40	40	17	22	30	20	40	40
	large scale farms [%]	-	-	20	20	60	60	83	78	70	80	60	60
Conservation agriculture	<i>overall share [%]</i>	0,5	1	30	90	20	25	28	25	30	70	10	15
	small scale farms [%]	-	-	50	40	40	40	70	60	30	50	30	30
	large scale farms [%]	-	-	50	60	60	60	30	40	70	50	70	70
Organic farming	<i>overall share [%]</i>	9	15	7	10	3	5	10	20	20	50	1	2
	small scale farms [%]	-	-	80	70	70	60	90	80	20	50	60	60
	large scale farms [%]	-	-	20	30	30	40	10	20	80	50	40	40
Bioenergy production	<i>overall share [%]</i>	1	3	3	15	5	8	10	30	5	30	1	2
	small scale farms [%]	80	-	80	60	40	40	10	5	10	30	40	40
	large scale farms [%]	20	-	20	40	60	60	90	95	90	70	60	60
Cooperative machinery use	<i>overall share [%]</i>	-	-	25	30	3	5	30	40	20	50	10	20
	small scale farms [%]	-	-	80	80	60	60	40	60	10	30	20	30
	large scale farms [%]	-	-	20	20	40	40	60	40	90	70	80	70

Source: Own data

The results related to the importance of organic farming also show positive trends, except for Cameroon and Botswana. While these two countries present the highest percentage of organic farming (50%), they expect a decrease of 10% and more in the next 10 years. In Italy, Finland and the USA, organic farming is well established with a growing share on cultivated area of around 10 %.

Within the sample, bio-energy cultivated area is the highest in the USA with 10%. In other surveyed countries, 5% is the maximum registered. These figures are expected to change over the next ten years. For example, China predicts that 30% of its agricultural area will be used for bio-energy production in the future. Similar

expansion is reported by the USA and South Africa assumes that the bio-energy production will cover 25 % of the agricultural area. Worth observing that large scale farms will dominate this type of production.

Table13: Selected issues of agriculture production: Share of total cultivated area - Africa

		Morocco		Cameroon		Botswana		South Africa	
		status	10 years	status	10 years	status	10 years	status	10 years
Irrigation	overall share [%]	15	40	0.3	0.6	10	30	10	20
	small scale farms [%]	10	30	50	50	20	30	0	5
	large scale farms [%]	90	70	50	50	80	70	100	95
Conservation agriculture	overall share [%]	2	10	50	60	2	5	10	25
	small scale farms [%]	0	5	80	60	50	50	0	10
	large scale farms [%]	100	95	20	40	50	50	100	90
Organic farming	overall share [%]	5	10	60	40	50	30	2	10
	small scale farms [%]	10	5	70	70	90	80	0	5
	large scale farms [%]	90	95	30	30	10	20	100	95
Bioenergy production	overall share [%]	0	0	2	5	0	5	5	25
	small scale farms [%]	0	0	30	40	/	50	0	5
	large scale farms [%]	0	0	70	60	/	50	100	95
Cooperative machinery use	overall share [%]	5	8	1	5	50	80	10	25
	small scale farms [%]	100	90	100	80	90	50	70	50
	large scale farms [%]	0	10	0	20	10	50	30	50

Source: Own data

Cooperative agricultural machinery use is a well developed scheme of mechanization all around the world, but at different scales as shown by the survey's results. In the case of France, Morocco, and Cameroon as well as in some regions of India and South Africa, this scheme is not often adopted with a maximum area covered of 10%. But, figures up to 50% of land cultivated under joint use of machinery are observed in Botswana and from 20 to 30% in countries like Finland, the USA and China. In the next ten years, it is expected that such scheme will become develop further in particular in China, Botswana and South Africa. Important to note in Asia cooperative machinery use is mainly practiced by large scale farms.

4.6 Future Market Penetration of Selected Technologies

Other main predictions which were analyzed relate to the agricultural sector application or adoption of high-tech innovative technologies like precision agriculture, smart implements, sensor technology, etc. Table 14 provides a tabular overview of the predictions resulting from the survey. In brief, precision farming is expected to be widely applied in developed as well as in emerging countries in the next ten years. Technologies that will reach significant market shares are in particular tillage, fertilizer application and plant protection. The market penetration of other innovative technologies such as ISOBUS, remote diagnostics or sensor technologies will later on see a notable development mostly in western countries. In the medium-term, driverless tractors will only be successful in the USA.

Table14: Market penetration of selected technologies

		Precision farming							Driverless tractors	Fleet management (telematics)	Smart implements	ISOBUS	Remote diagnostics	Use of sensor technology	Robotics
		Overall	Tillage	N-fertilizer application	Other fertilizer application	Plant protection	Guidance systems	Yield mapping							
Germany	status	4	5	5	5	5	4	4	1	2	1	3	3	4	3
	10 years	5	5	5	5	5	5	5	1	5	2	4	4	5	4
Italy	status	2	2	-	-	4	2	2	1	2	1	1	1	1	1
	10 years	3	3	-	-	5	3	3	2	2	2	3	3	2	2
France	status	2	1	2	1	2	1	2	1	2	2	2	1	2	1
	10 years	3	2	4	3	4	3	4	2	3	4	4	3	4	2
Finland	status	2	1	2	2	1	2	2	1	1	2	2	1	2	1
	10 years	3	2	3	3	4	5	3	1	2	4	4	4	4	2
USA	status	5	5	5	5	5	5	4	1	3	2	2	3	3	2
	10 years	5	5	5	5	5	5	5	3	4	4	4	5	5	4
Japan	status	1	5	1	5	5	2	1	1	-	-	1	1	1	2
	10 years	3	5	1	5	5	3	1	1	-	-	4	2	3	3
China	status	1	1	4	4	3	1	1	1	1	1	1	1	1	1
	10 years	3	2	5	5	5	2	2	2	3	3	3	2	3	2
India	status	1	3	4	2	3	1	1	1	1	1	1	1	1	1
	10 years	2	4	5	3	4	1	1	1	1	2	1	1	1	1
Marocco	status	1	4	3	3	3	1	1	1	1	1	1	1	1	1
	10 years	2	5	4	4	4	2	2	1	2	2	2	2	2	2
Cameroon	status	1	2	1	1	1	1	1	1	1	1	1	1	1	1
	10 years	1	2	2	2	1	1	1	1	1	1	1	2	2	1
Botswana	status	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	10 years	2	3	3	2	3	1	2	1	1	1	1	1	1	1
South Africa	status	3	5	5	5	5	2	2	1	1	1	1	1	1	1
	10 years	4	5	5	5	5	3	3	2	2	2	3	3	3	2

Legend:



Source: Own survey

5. Conclusions

The need for further mechanization to improve productivity in agriculture and to feed the world is undisputable in particular in the light of expected demographic developments. According to the survey results the mechanization level in agriculture still depends on the overall level of industrial development. In developed countries mechanization is far advanced and further demand exists mainly for advanced technologies. The use of precision farming will become standard in the short to the mid-term range, but also the use of control and automation systems will become common and offer new growth opportunities for the corresponding branches.

The political conditions and also expected socio-development factors seem to be very favorable for investments in agricultural mechanization. Nevertheless, the quantitative saturation of domestic markets with a large number of different agricultural implements will force the industry to open potentials abroad. In fact at present, the developing industry in emerging economies is often dominated by branches and joint ventures of companies from the USA, the EU and Japan.

The emerging countries such as India, China and South-Africa are seeing significant economic growth with associated technology transfer and progress in agricultural production. They are becoming important players on the world markets for agricultural machinery and also represent promising markets with high demands for further mechanization. Strong advances towards high levels of mechanization can be expected. However, this support that: (i) the current trends of technology transfer is pursued as part, for example of joint-ventures; and (ii) issues like e.g. property rights, different taxation practices across countries and unequal subsidies, market access, etc. are further dealt with.

The most challenging region for agricultural mechanization development remains Africa. While only limited progress has been achieved in terms of increased number of machines and market expansion, the predictions over the next ten years are positive. This supposes that increased investments are needed both from the national governments and the private sector to develop the domestic manufacturing industry.

References

- Alston, J.M., Babcock, B.A. and Pardey, P.G. (2010), *The shifting patterns of agricultural production and productivity worldwide*, The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa.
- Ashburner, J.E. and Kienzle, J. (2011), *Investment in agricultural mechanization in Africa: Conclusions and recommendations of a round table meeting of experts*, FAO, Rome.
- Bishop-Sambrook, C. (2005), "Contribution of farm power to smallholder livelihoods in sub-Saharan Africa", available at: <ftp://ftp.fao.org/docrep/fao/009/a0229e/A0229E00.pdf> (accessed 20 February 2013).
- Böttinger, S., Doluschitz, R., Volz, R., Jenane, C. and Paterson, J. (2011), *World Trend and Evolution of the Agricultural Machinery Manufacturing Sector, Agrievolution 2010*, Waldorf-Astoria, Orlando.
- Böttinger, S., Doluschitz, R., Volz, R., Paterson, J. and Jenane, C. (2010), "World trend and evolution of agricultural machinery manufacturing sector", paper presented at International Conference on Agricultural Engineering - AgEng 2010, 06.-08.-09.2010, Clermont-Ferrand, France.
- Casão Junior, R., Araújo, A.G.d. and Llanillo, R.F. (2012), *No-till agriculture in southern Brazil: Factors that facilitated the evolution of the system and the development of the mechanization of conservation farming*, FAO; Agricultural Research Institute of Paraná State, Rome, Paraná.
- Da Silva, C.A. (2009), *Agro-industries for development*, CABI; Food and Agriculture Organization of the United Nations, Wallingford, UK, Cambridge, MA, Rome.
- Department of Economic and Social Affairs of the United Nations (2011), "World Population Prospects: The 2010 Revision. Volume I: Comprehensive Tables", available at: http://esa.un.org/wpp/Documentation/pdf/WPP2010_Volume-I_Comprehensive-Tables.pdf.
- Department of Economic and Social Affairs of the United Nations (2011), "World Population Prospects: The 2010 Revision. Volume II: Demographic Profiles", available at: http://esa.un.org/wpp/Documentation/pdf/WPP2010_Volume-I_Comprehensive-Tables.pdf.
- Fan, S. and Pandya-Lorch, R. (Eds.) (2012), *Reshaping agriculture for nutrition and health*, International Food Policy Research Institute, Washington, D.C.

- Food and Agriculture Organization of the United Nations (FAO) and RUAF Foundation (Eds.) (2010), *Food, Agriculture and Cities: challenges and way forward: Technical consultation*, Rome.
- Fuglie, K.O., Ball, V.E. and Wang, S.L. (2012), *Productivity growth in agriculture: An international perspective*, CABI, Wallingford.
- Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. and Toulmin, C. (2010), "Food Security: The Challenge of Feeding 9 Billion People", *Science*, Vol. 327 No. 5967, pp. 812–818.
- Guadagni, M. and Fileccia, T. (2009), "The Kyrgyz Republic. Farm mechanization and agricultural productivity", available at: http://www.fao.org/fileadmin/user_upload/tci/docs/CH1-Kyrgyz%20Republic_Farm%20mechanization%20&%20agricultural%20productivity.pdf .
- Mazoyer, M. (2001), *Protecting small farmers and the rural poor in the context of globalization*, Rome.
- Msangi, S. and Rosegrant, M.W. (2012), "Feeding the Future's Changing Diets: Implications for Agriculture Markets, Nutrition, and Policy", in Fan, S. and Pandya-Lorch, R. (Eds.), *Reshaping agriculture for nutrition and health*, International Food Policy Research Institute, Washington, D.C, pp. 65–72.
- OECD (2012), "Sustainable Agricultural Productivity Growth and Bridging the Gap for Small-Family Farms. Interagency Report to the Mexican G20 Presidency", available at: <http://www.oecd.org/tad/agricultural-policies/sustainableagriculturalproductivitygrowthandbridgingthegapforsmall-familyfarms.htm>.
- OECD and Organization, F.a.A. (2012), *OECD-FAO Agricultural Outlook 2012*, Organization for Economic Co-operation and Development, Paris.
- Prakash, A. (Ed.) (2011), *Safeguarding food security in volatile global markets*, FAO, Rome.
- Rasouli, F., Sadighi, F. and Minaei, S. (2009), "Factors Affecting Agricultural Mechanization: A Case Study on Sunflower Seed Farms in Iran", *Journal of Agricultural Science and Technology J. Agric. Sci. Technol*, Vol. 11, pp. 39–48.
- Rijk, A.G. (2012), "Agricultural Mechanization Management", available at: http://www.unapcaem.org/publication/CIGR_APCAEM_Website.pdf.
- Schmidhuber, J. and Bruinsma, J. (2011), "Investing towards a world free of hunger: lowering vulnerability and enhancing resilience", in Prakash, A. (Ed.), *Safeguarding food security in volatile global markets*, FAO, Rome, pp. 523–549.
- Sims, B.G. and Kienzle, J. (2009), *Farm equipment supply chains: Guidelines for policy-makers and service providers experiences from Kenya, Pakistan and Brazil*, FAO, Rome.
- The World Bank (2007), *Agriculture for development, World development report*, Vol. 2008, World Bank, Washington, D.C.
- The World Bank (2012), *Jobs, World development report*, Vol. 2013, Washington, DC.
- The World Bank (2013), "World Development Indicators", available at: <http://data.worldbank.org>.