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Transforming West African agriculture through the development of mechanization: what public policies?

Keynote Address

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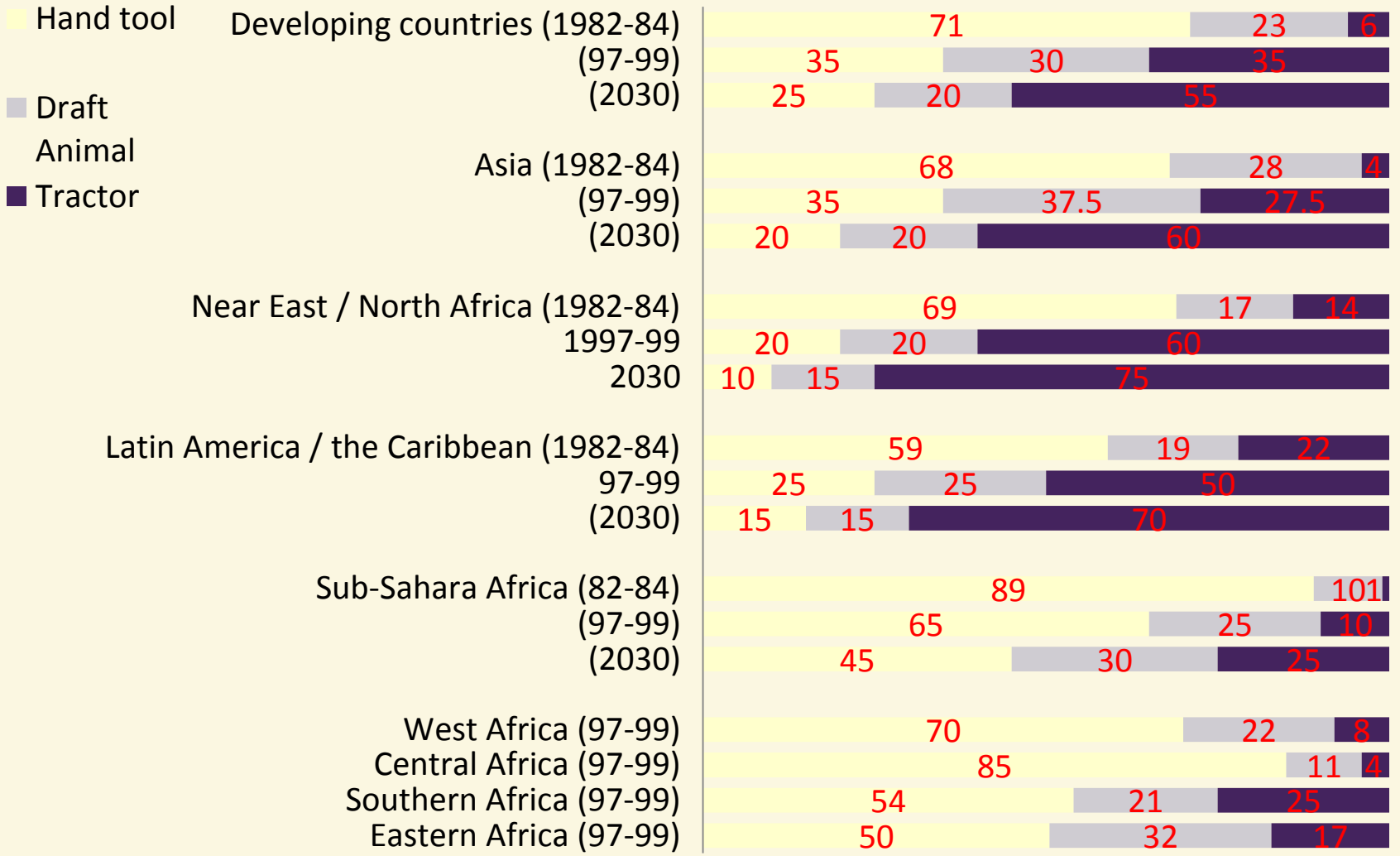
Outlines

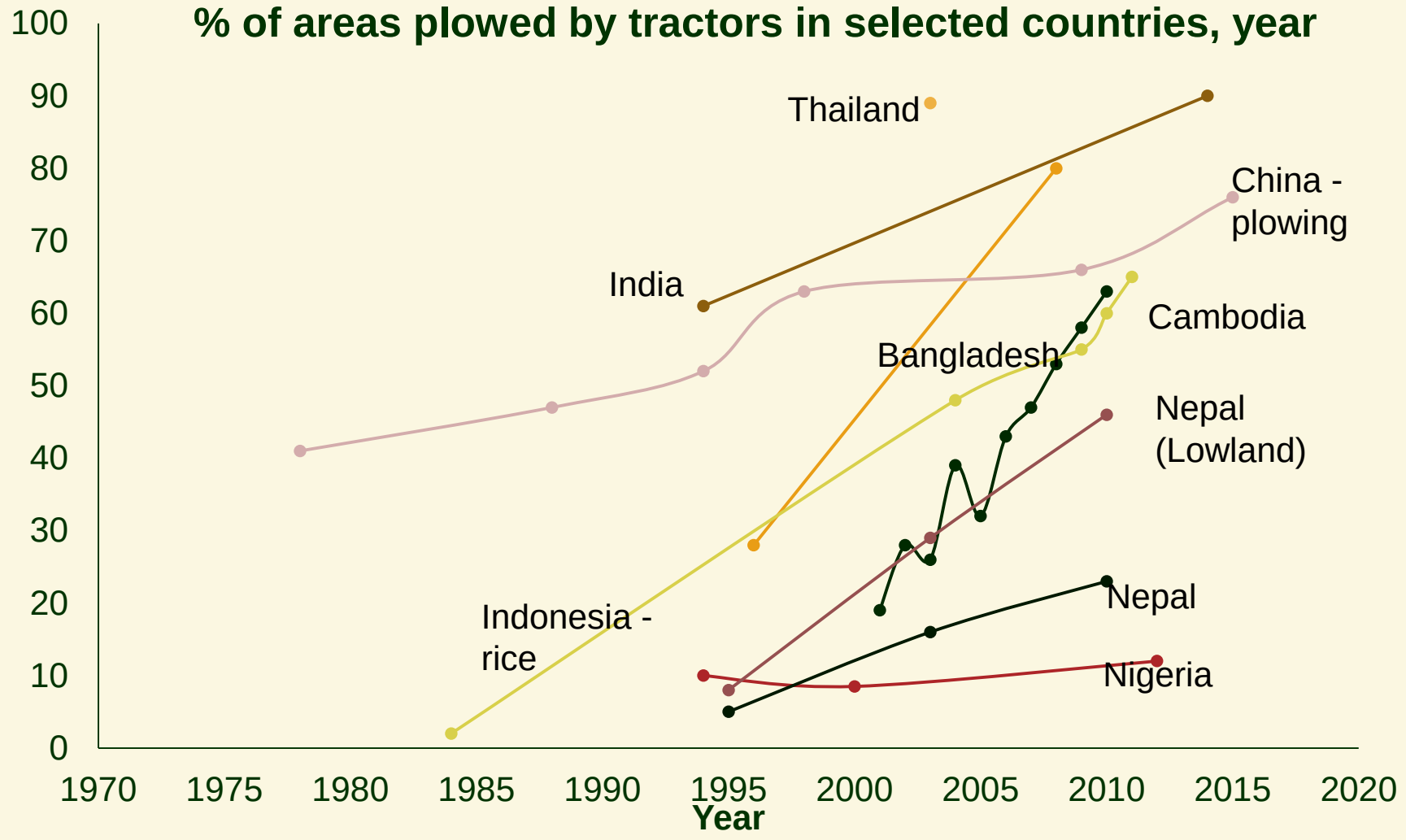
- **Patterns of mechanization growths in West Africa and elsewhere**
- **Private sector in mechanization growth**
  - Custom hiring service in West Africa - growths and challenges
- **Agricultural mechanization policy issues**
  - Broad agricultural policies and mechanization specific policies, government's role
  - Experiences in Nigeria
- **Concluding remark**

Agricultural mechanization has been slow in Sub-Saharan Africa, including West Africa

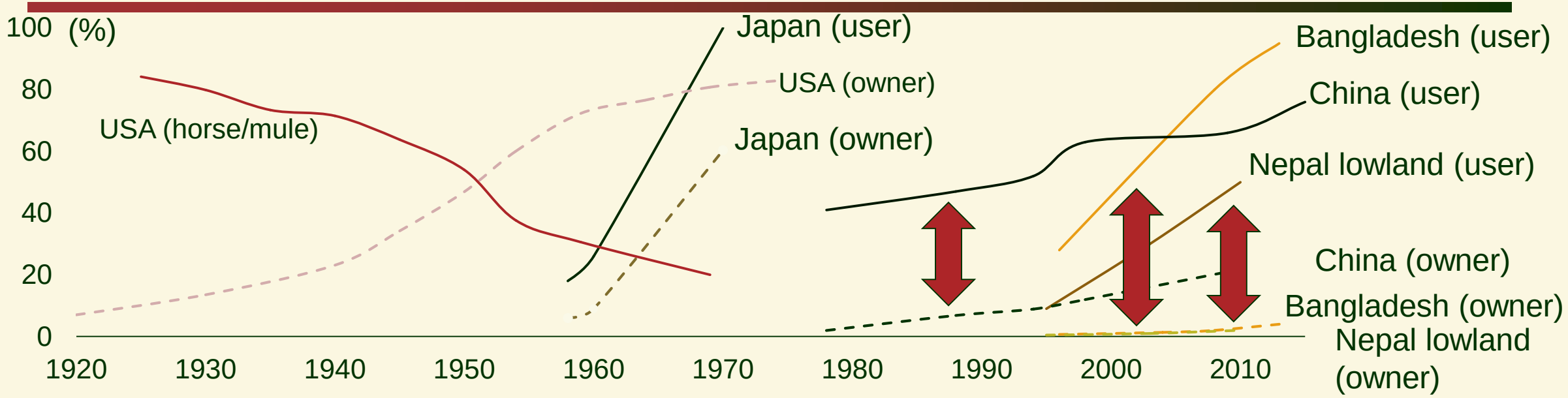


Share (%) of land cultivated by different tools / machineries
Source: Grigg (1984), Mrema et al. (2008), Takeshima & Salau (2010)

In Asia, tractor use has grown rapidly in the last few decades



Recent tractor use growth in Asia has been through custom hiring, rather than ownership growth



In the US or Japan, early tractor uses grew through **ownership growth**

*US: ownership of horses/mules declined in response to tractor ownership => indicates tractor ownership rather than rental primarily replaced horses/mules

Recent tractor use growth in developing countries has been mostly through **custom hiring**, rather than ownership growth

Indivisible tractor technologies are made scale-appropriate through custom-hiring in many developing countries today

In Asia, tractor use grew while many workers remained in agriculture. Same is possible in West Africa

In the past, mechanization occurred only after the agricultural transformation had occurred

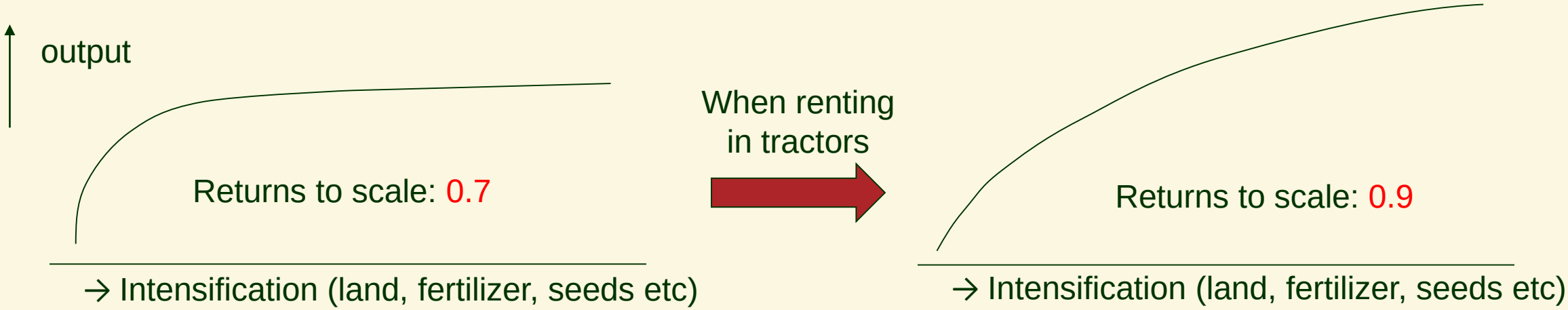
Mechanization today can both retain smallholders, and also transform smallholder farming systems

Would these patterns apply to West Africa ?

Source: Presenters based on various studies

In Asia, mechanization not only substituted labor, but also have raised returns-to-scale

Change in the shape production function

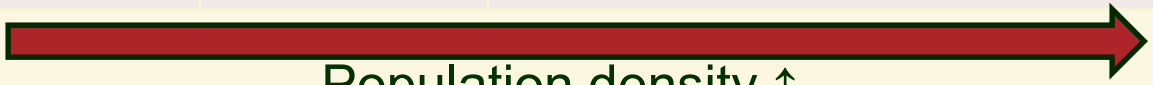


Source: Takeshima (2017).

⇒ Transformative effects on smallholder agriculture
- ⇒ inputs-use intensifications
- ⇒ Specialization
- ⇒ Divisions of labor

In West Africa, demand for mechanization still largely depends on farming system evolution

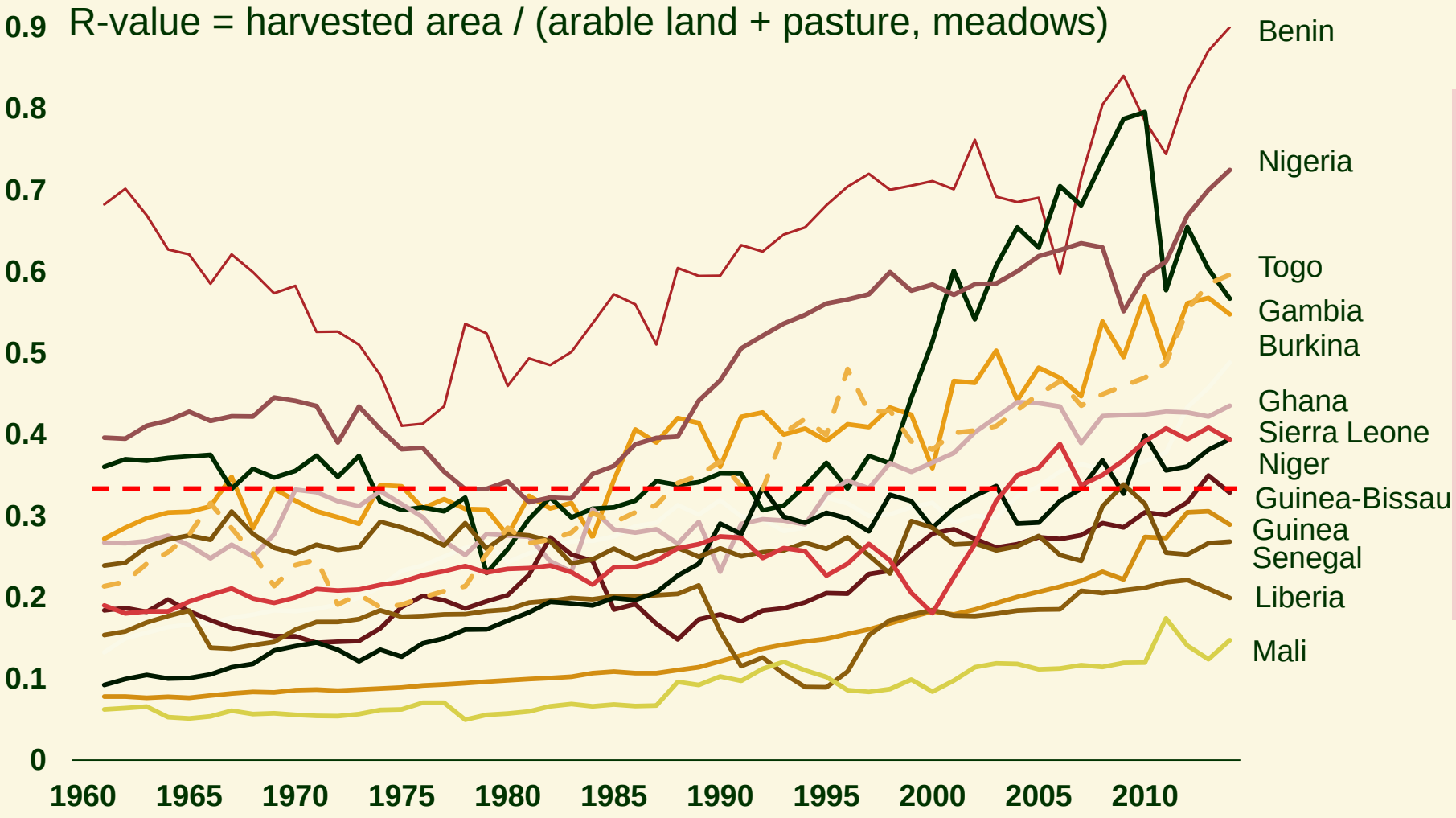
	Forest fallow (Slush & burn)	Bush fallow	Short / grass fallow	Annual cultivation	Multiple cropping
Fallow period	20 years ~	6 – 10 years	1 ~ 2 years	~ 1 year	No
Cropping	1 – 3 years	1 – 8 years	Several	A few months	
Population	~ 10 / km^2				
Land clearing	Fire	Fire			
Land preparation	Digging stick	Hoe/digging stick	Plow	Animal-drawn plow Tractors	
Weeding		Some	Intensive		
Use of animals			Plowing Transport	Plowing, Transport, Post-harvest, Irrigation	
Labor demand		Weeding	Land preparation, Weeding, Harvesting		



Population density ↑
Market infrastructure ↑

Source: Modified from Boserup (1965), Binswanger and Pingali (1988), Windmeijer and Andriesse (1993)

In West Africa, farming intensification has exceeded the level at which mechanization demand starts growing



Source: Presenter's calculations based on FAOSTAT

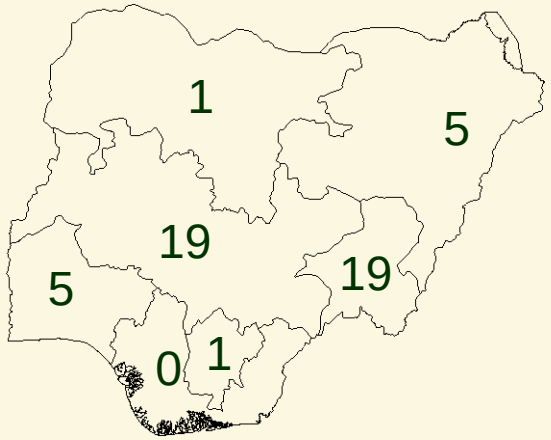
Farming intensification often raises demand for more farm power uses

Example: R-value = 0.33
Switch from long-fallow to short fallow, and increased uses of animal tractions (Boserup 1965; Ruthenberg 1980; Diao et al. 2014)

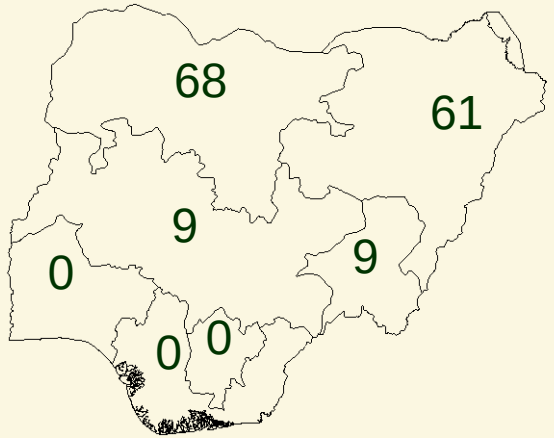
Mechanization patterns are diverse: vary across regions, and crops (and across countries)

Share (%) of land plowed by tractors or draft animals in Nigeria (2010/12)

Tractors



Draft animals



Crops	% of crop area using tractors (Nigeria, 2010/12)
Rice	31
Maize	6
Sorghum	5
Millet	2
Cowpea	4
Ground nuts	3
Cassava	3
Yam	2
Vegetables	1

Source: LSMS-ISA (2010/2012)

Use intensity of animals is still low in Nigeria: demand for mechanical farm power (tractors) still insufficient?

Country / regions	Reference year	Animal tractions (days / per farms, year)	Source:
Nigeria - North West	2010/12	**6**	LSMS-ISA
Nigeria – North East	2010/12	**9**	LSMS-ISA
Bangladesh	Early 1990s	**90**	Mandal & Parker
Japan	1950s	**30**	Government of Japan
Thailand	1991	**15**	Pryor (1992)
USA	1930s	**100 (including other uses)**	Jasny (1935)

Note: The figures are derived by the presenters from the original sources, and can differ considerably depending on the assumptions used.

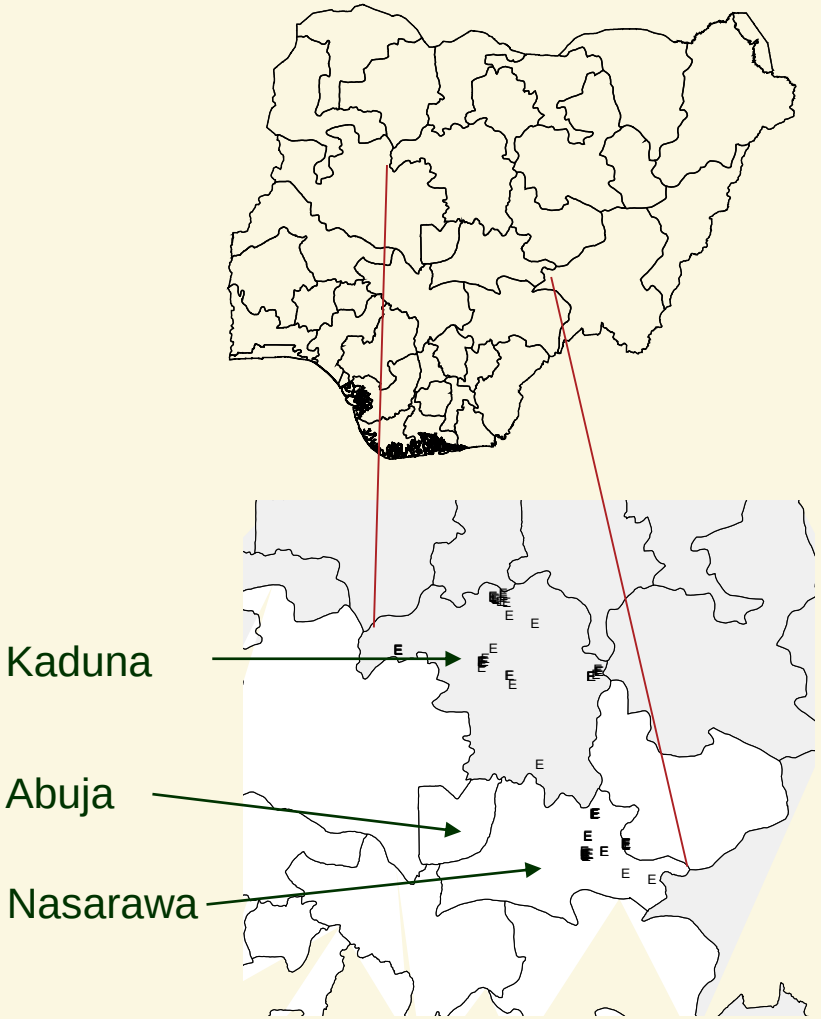
Private sector has emerged as efficient service providers

CUSTOM HIRING SERVICES OF TRACTORS IN WEST AFRICA

Among various types of custom hiring services, farmer-to-farmer model is often the most common

No	Types of CHS providers		Cultivate own farm	Ownership of tractors / power tillers	Sources of tractors	Share in Ghana / Nigeria
1	Specialized service providers		No	Individual	Government selected suppliers	Rare
2	Cooperative / Joint ownership		Yes	Joint	Often government selected suppliers	Rare
3	Farmer-to-farmer	Government-sourced	Yes	Individual	Government selected suppliers	Relatively common
4	Farmer-to-farmer	Market-sourced	Yes	Individual	Market	Most common

Examples in Central Nigeria



Two types of tractor owners identified based on the sources of tractors

Government-sourced (GS) owners

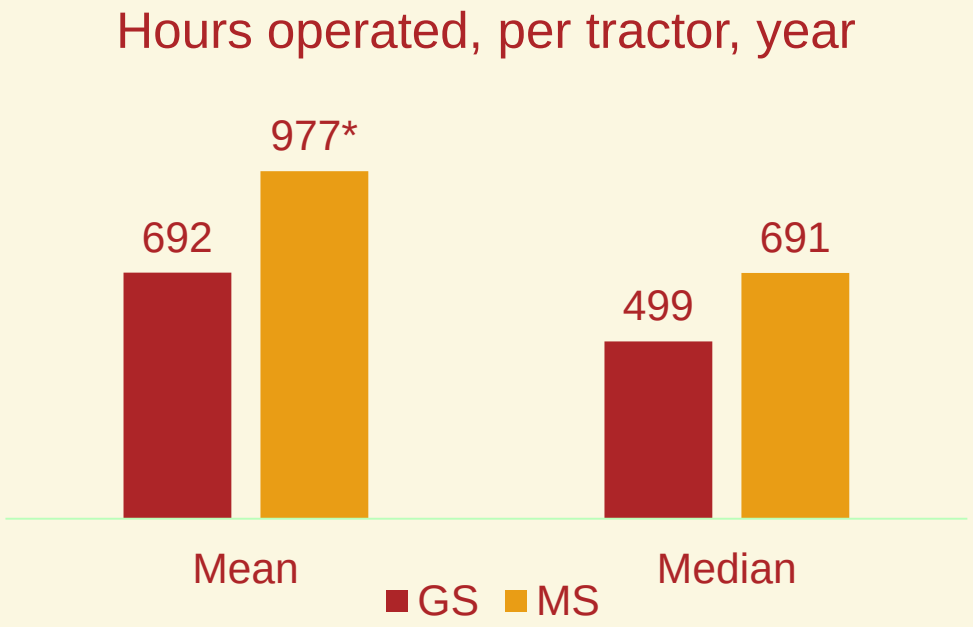
Obtained tractors only through government scheme

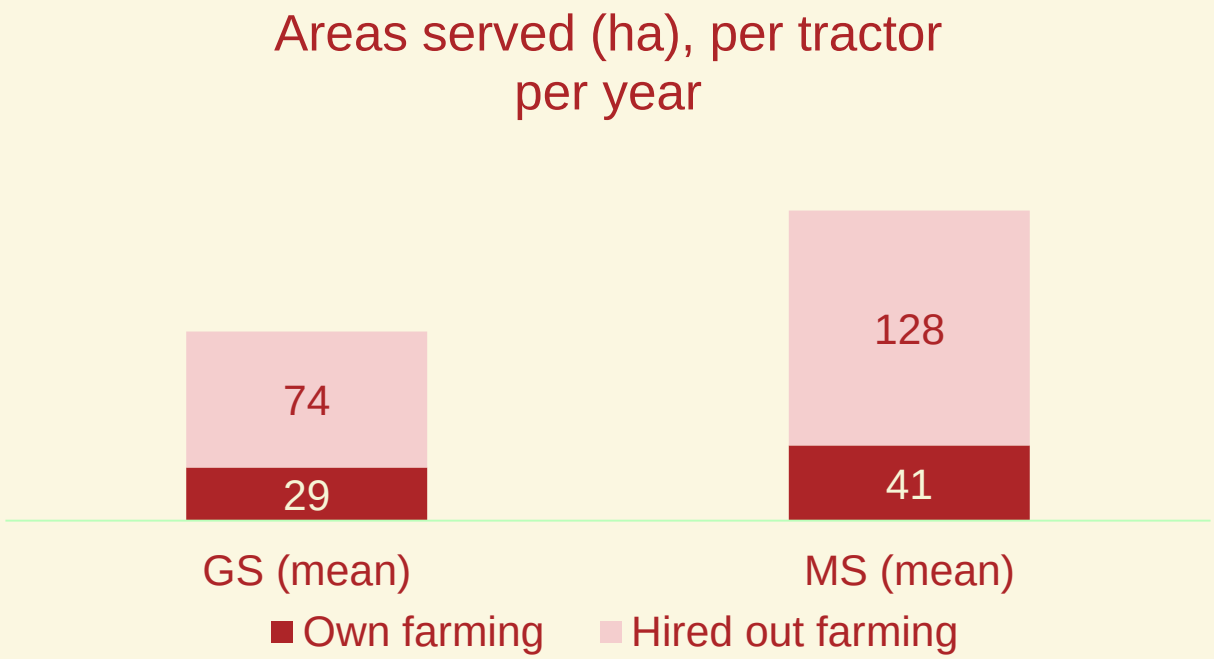
Market-sourced (MS) owners

Obtained tractors through private market, private individuals

Tend to be more efficient

Market-sourced owners use tractors more extensively than *government-sourced* owners





Source: Presenter's calculation based on survey.

MS owners operate longer hours, serve more areas than *GS* owners

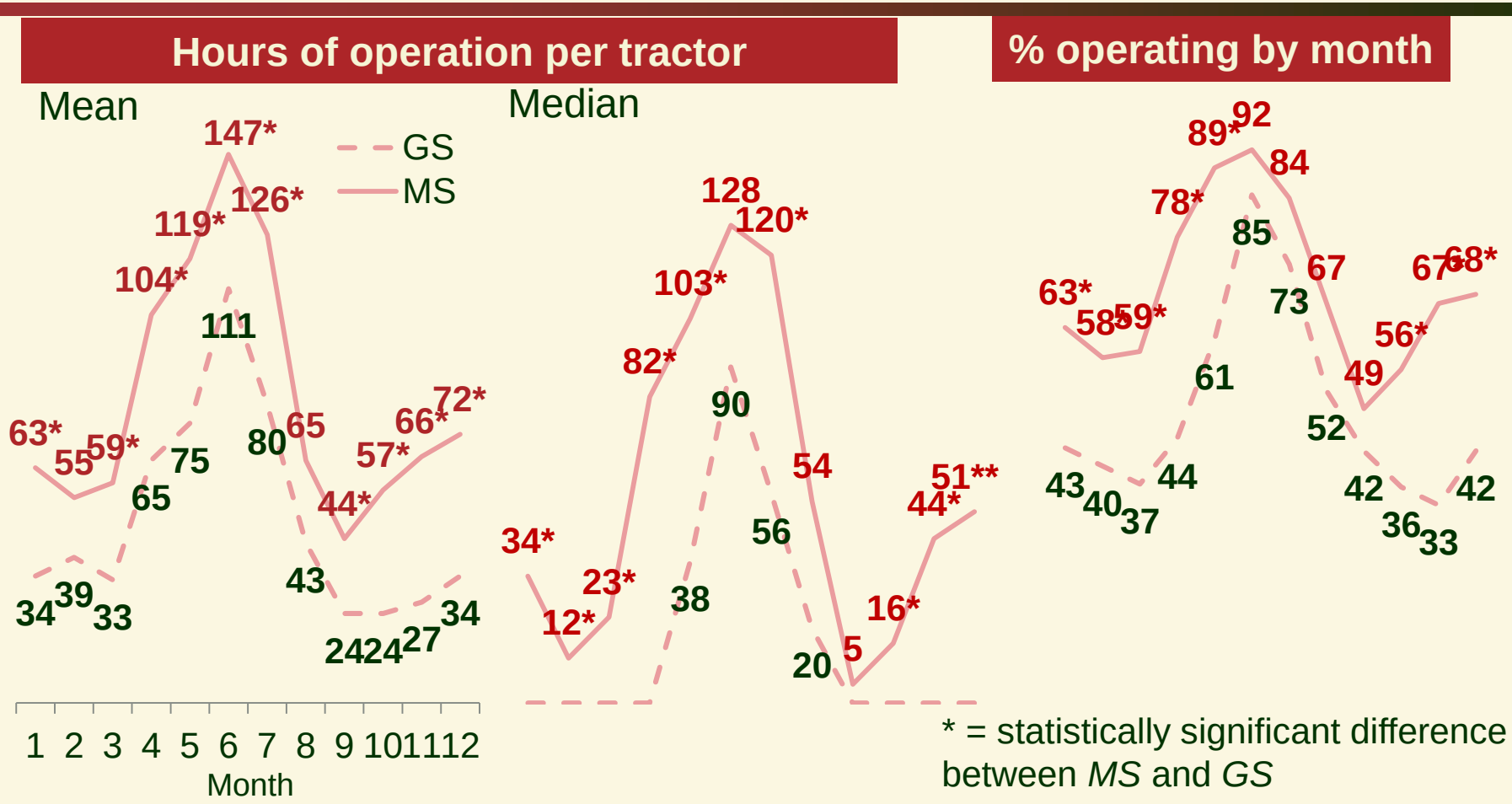
Market-sourced owners realizes higher profitability than *Government-sourced* owners

Benefits from tractor use in the last 12 months (current USD 1,000)

	GS		MS	
	Median	Mean	Median	Mean
Total gross revenues per year	**5**	**8**	**11***	**13***
Monetary values of own-farm use	*1*	*2*	*3*	*4*
Gross earnings from hiring out	*4*	*6*	*6*	*9*
Payment for operators and fuels	**1**	**3**	**3**	**5**
Operators	*0*	*1*	*1*	*2*
Fuels	*1*	*2*	*2*	*3*
Repairing	**1**	**1**	**1**	**1**

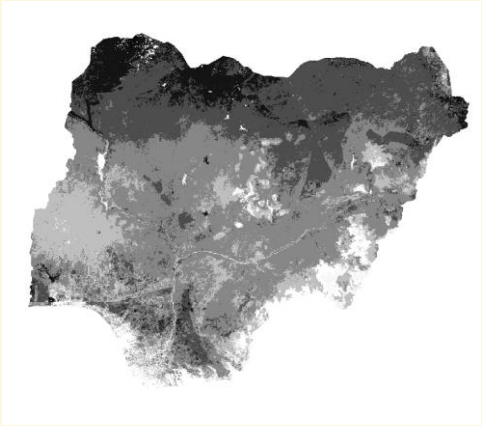
- *MS* owners earn significantly more than *GS* owners
- Revenues are much greater while operators / fuels costs are similar

Tractor use highly seasonal but *Market-Sourced* owners are more active all-year around



Substantial seasonality
But *MS* owners – mitigate seasonality; still find some work in off-season

Market-sourced owners may have knowledge of soil types and appropriate horsepower



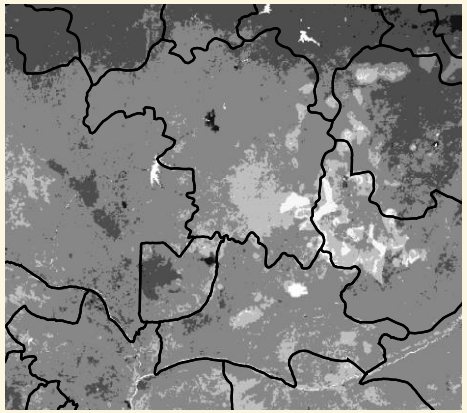


Figure 4. Bulk density of soils in Kaduna and Nasarawa (darker = heavier soils)
Source: ISRIC (**International Soil Reference and Information Centre**) (2013).

Correlation between the tractor horsepower and bulk density of soil – *MS* owners (conditional on operating outside the home LGA)

	Kaduna			Nasarawa			Both	
	N of obs	Corr. Coefficient		N of obs	Corr. Coefficient		N of obs	Corr. Coefficient
Could select from a range of horsepower	138	**.196***		26	**.577****		164	**.241****
All	238	.011		71	.180		309	-.027

Source: Presenters.

MS owners who could select from a range of horsepower
⇒ travel more to heavy soil area if they have higher horsepower tractor
⇒ Some indication: *MS* owners can use tractor efficiently based on soil type
(no such patterns among GS owners)

Power tiller service providers
Kpong Irrigation Scheme, Ghana

Brief description of Kpong irrigation scheme

- One of 22 irrigation schemes in Ghana
- 4000 ha of rice area (2000 ha X two seasons)
- 2500 registered farmers (mostly indigenous farmers)
- Opened in 1959
- Aromatic rice production (Jasmine 85, etc) since 2009
- Yield = close to 6 tons / ha

Power tiller use

- 100% of irrigated rice area (4000 ha) prepared by power tillers
- Private custom hiring with 50 ~ 100 power tillers
- Power tillers introduced by the government, donors, private companies since 80s
- Growing share of power tillers sourced directly from private market (20 – 50%)

Market-sourced power tiller service providers seem more efficient than government-sourced owners

Profitability of power tiller service provisions by two-types of power tiller owners (USD / year)

	All	Obtained power tillers from private sector	Obtained power tillers from government
Categories	USD / year	USD / year	USD / year
Fuel cost	562	626	421
Lubricant cost	184	195	159
Repair cost	424	422	428
Spare parts	570	473	775
Workmanship cost	246	231	280
Operators	513	537	459
Depreciation of power tiller (assuming 5 years) [a]	713	773	576
Depreciation of implements (assuming 5 years) [b]	316	359	316
Revenue [c]	3675	3971	3008
Total area plowed (ha)	23	25	19
Revenue per ha (USD / ha)	158	159	157
Profit	263	542	-311

[a] Based on the (1) power tiller price = $3000; (2) average number of power tillers owned = 1.15.

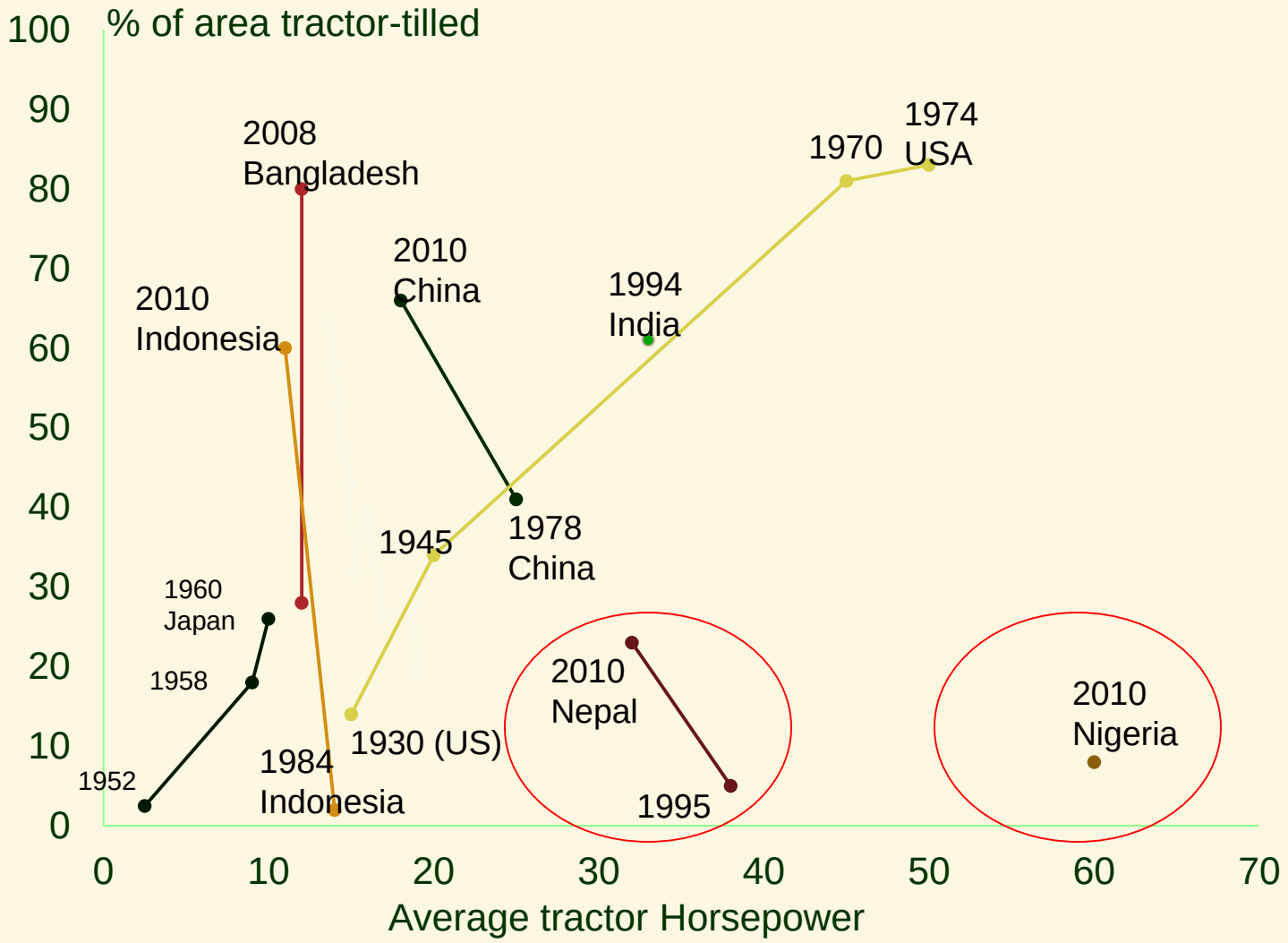
[b] Assuming that the original value is twice that of current value of implements, and they typically last 5 years.

[c] Imputed revenues for own farm use are included.

Most tractors are purchased using personal savings; credit is sometimes provided by tractor importers / retailers

- In Nigeria / Ghana:
  - personal savings are generally dominant source of tractor finance
  - the dominance of expensive, high horsepower tractors aggravate this condition
- In Asia, credit is mostly provided by tractor importers / retailers who also have sufficient know-how of loan management (with specific divisions dedicated for it)
  - Bangladesh
  - Transactions costs are high for monitoring payments and insuring default risks; but the private sector still has incentives as the demand is high enough to bring profits
- Challenges for some finance mechanisms

Challenges in West Africa: tractors are large but very few



Many countries started out with low horsepower (10HP) at early stage of tractor use growth

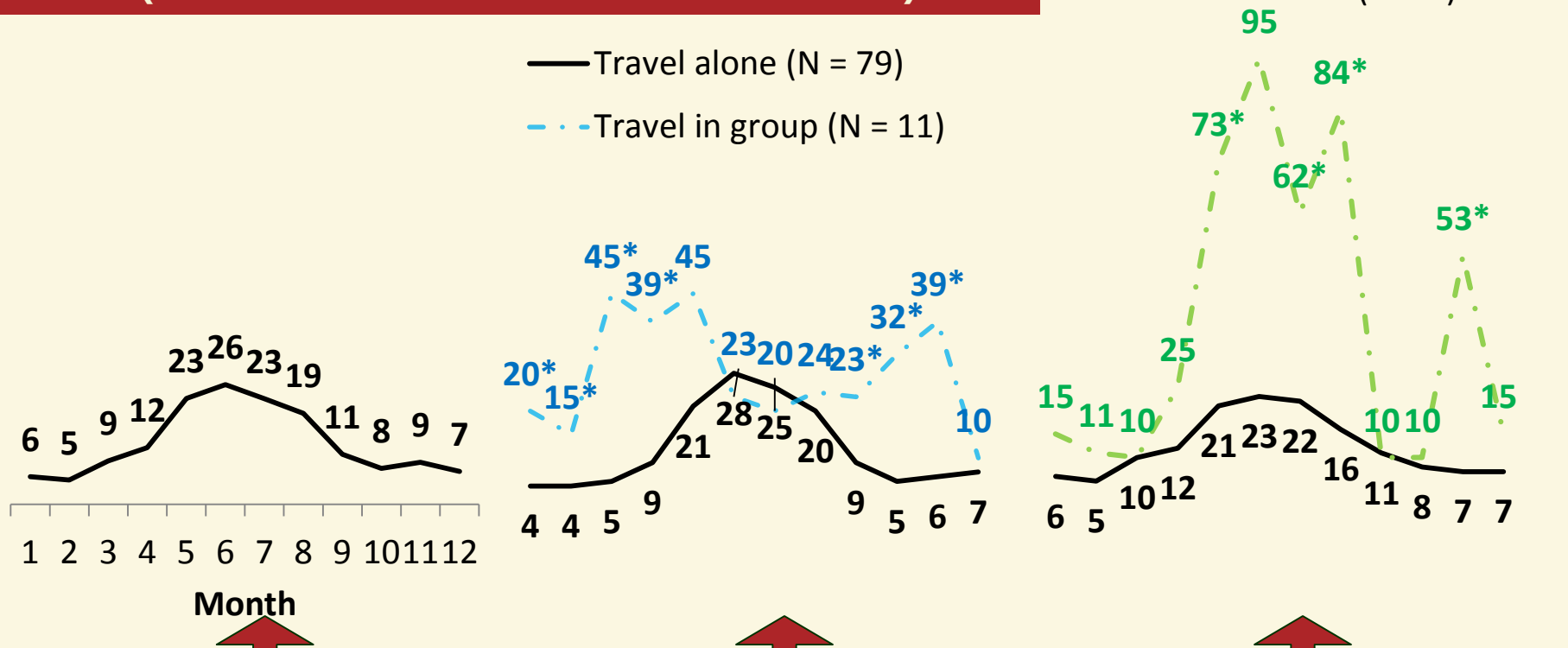
High average horsepower in low tractor adoption environment – only recent phenomena observed in Sub-Saharan Africa

Indivisibility with tractors is more serious

Scale of mechanization is definitely an issue

Challenges – mobility of tractor is limited, except small clusters of long-distance travelers

Average distance (km) away from home district in each month (Euclidean distance from home district)



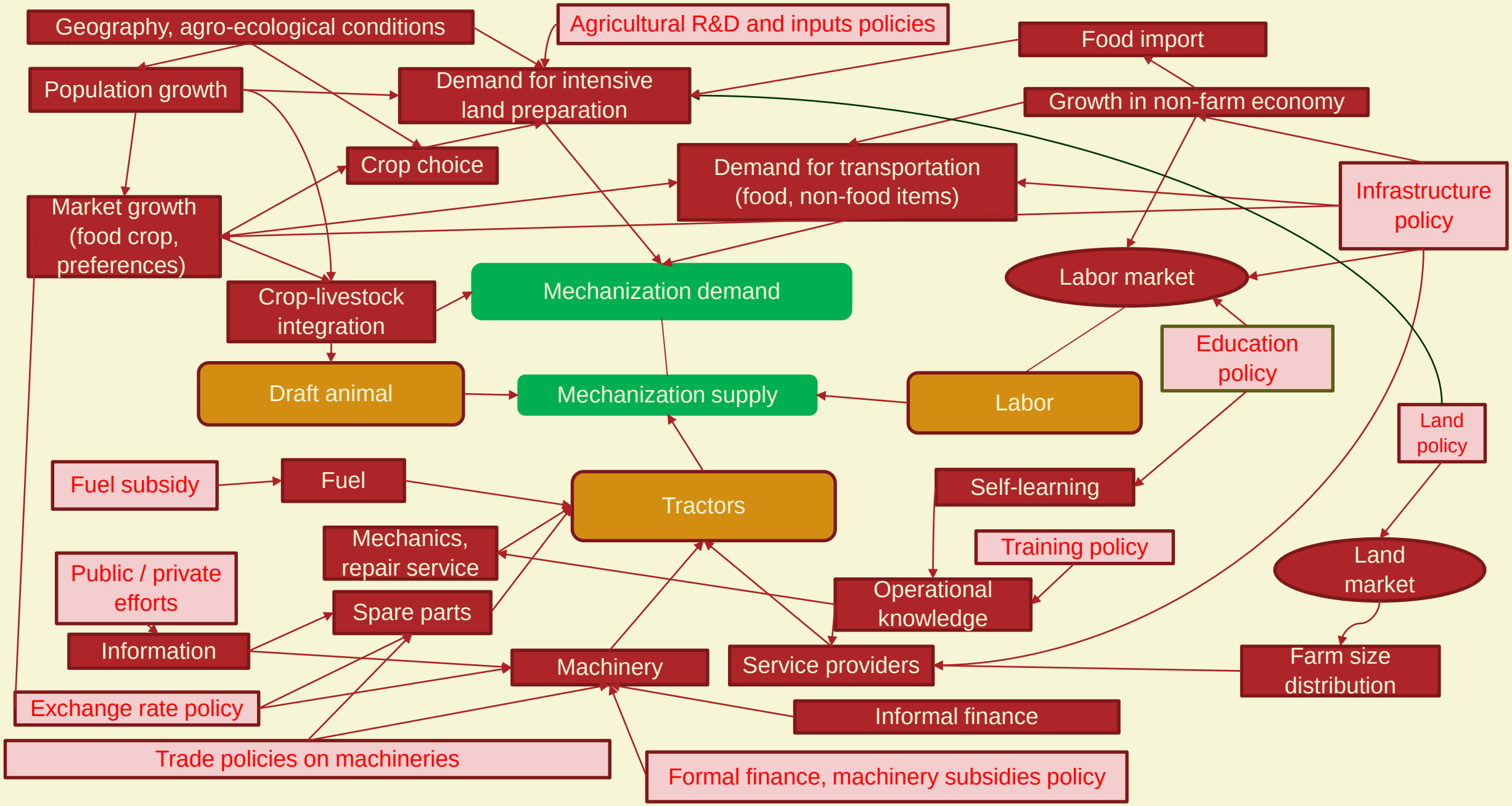
- Travel is generally confined within 25 km radius (Euclidean distance)

Group traveler –
- travel further away in off-season

Truck traveller (10% of sample)
- travel further away in peak-season

AGRICULTURAL MECHANIZATION POLICY ISSUES

Complex impact pathways of broad economic policies and mechanization specific policies



Agricultural mechanization policy issues

- Mechanization
  - is affected more by a broader set of agricultural and economic policies
  - is also affected by mechanization-specific policies, but in more limited scope
- Private sector can often meet the demand (if the demand is sufficient)
  - Investment in machines
  - Provisions of services, spare parts, repairs
  - Innovation; engineers in the private sector are often as capable as those in public research institutions; different from innovations on some other technologies (eg, improved varieties)
- Government can focus more on gathering information and knowledge through research:
  - Effects of broad policies on mechanization, and their mechanisms
  - Extent and nature of private sector activities, and where exactly government needs to fill the gap
  - Experiences in foreign countries

Tractor related policies have had mixed effects on overall mechanization growth in Nigeria

Periods	-1972	1973-85	1986-99	2000-12	2013 -
Adoptions (%) – Tractors	**1 ~ 5**	**5 ~ 10**	**10**	**8**	**10 +**
Adoptions (%) – Animal traction		**3 ~ 4**		**25**	**25 +**
Animal traction (North)		**6 ~ 10**			**60**
Subsidies: - Subsidized distribution of tractors (fixed amount) - (in the form of interest rate subsidy)		Large import and subsidized distribution (as many as 3000 tractors / year)	Occasional distribution of subsidized tractors by both Federal and State governments (generally inefficient targeting)		**Federal**: switch to support for service provider **States**: continue subsidized distribution of tractor
Trade policies	Generally liberalized	Import duties for spare parts raised	Devaluation following SAP (8- fold increase in tractor price) Tractors often VAT-exempt Import duties; 5% for spare parts; varied between 0 ~ 25% for tractors		
Fuel prices (diesel)	Unregulated	Price control Enhanced domestic refinery capacity	Government control of fuel imports	Diesel - unregulated since 2007 Kerosene / gasoline remain subsidized	
Industrialization policies (domestic manufacturing)	Joint venture unsuccessful due to poor raw materials				
Agricultural R&D	Release of farm-power-responsive varieties (responsive to intensive tillage – maize, for example) => growth of animal tractions thereafter		Reduced support for NARS and reduced farm-power-intensive crops (limited response to intensive tillage, and demand for farm-power) Growing food import to fill production shortage		
Agricultural R&D	Limited effort in public knowledge accumulation (tractor census, agricultural mechanization statistics, etc)				

Concluding remark

- Mechanization growth in developing countries in the last 25 years
  - widespread mechanization growth is possible for smallholder farmers
  - mechanization can grow even when many workers are employed in agricultural sector
  - mechanization has transformative effects, rather than simply substituting labor
- In West Africa, overall demand for mechanization is still largely affected by farming system evolution
  - the demand has grown sufficiently high in some areas, but has remained low in other areas
- Where the growth has occurred, private sector has often emerged as efficient suppliers of custom-hiring services
- However, accessibility is still constrained
  - Tractors are large but few - we need to know more about the optimal size of machines in West Africa (animals, small pumps, motorcycles are commonly adopted – why not small tractors?)

Concluding remark

- Agricultural mechanization policies
  - Agricultural mechanization is affected by broader set of policies, rather than mechanization-specific policies
- Important to increase overall support for agricultural sector
  - CAADP target – allocate 10% of government spending to agriculture
  - Agricultural R&D; develop varieties that respond to intensive tillage
  - Agricultural R&D on mechanization: gathering information on
    - which factors raise demand for intensive farm-power uses
    - what the private sector is doing (investment in machines, mechanization service provisions etc)
    - situations in other countries (the designs of machineries used, etc)
  - Infrastructure development
    - rural electrification – lowered the costs of mechanical water pumping in South Asia
    - rural road infrastructure

References

Diao X, J Silver & H Takeshima. (2016). *Agricultural Mechanization and Agricultural Transformation.* IFPRI Discussion Paper 01527.

Hayami Y & VW Ruttan. (1985). *Agricultural development: An international perspective.* Baltimore and London: The John Hopkins University Press.

Hayami Y & T Kawagoe. (1989). Farm mechanization, scale economies and polarization: The Japanese experience. *J. Devel. Econ. 31*(2), 221-239.

Takeshima H, E Edeh, A Lawal & M Isiaka. (2015). Characteristics of private-sector tractor service provisions: Insights from Nigeria. *Developing Economies 53*(3), 188-217.

Takeshima H, R Adhikari & A Kumar. (2016). *Is access to tractor service a binding constraint for Nepali Terai farmers?* IFPRI Discussion Paper 01508.

Takeshima H. (2016). Custom-hired tractor services and returns to scale in Nepalese smallholder agriculture: A production function approach. *Agricultural Economics*, forthcoming.

Zhang X, J Yang & T Reardon. (2015). *Mechanization Outsourcing Clusters and Division of Labor in Chinese Agriculture*. IFPRI Discussion Paper 01415.

THANK YOU !