Supplementary material for:

Agricultural mechanisation could reduce global labour requirements by hundreds of millions of agri-food workers

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Table 1 a-b. a Technological-use catching up of crop production systems by the different field size classes in the increased mechanisation scenarios. In the incremental change scenario (MDA_{INCRE}), each class is matched with the next, larger field size class (except for "Large" which remains the same). In the very fast transition scenario (MDA_{INCRE}), all classes are matched with the highest labour productivity class (which here corresponds to the "Large" field size). The development here includes only the labour requirements and not the actual field sizes b Mechanisation development of livestock production systems. In the realistic scenario (MDA_{INCRE}) livestock systems are catching up with the next more labour-productive class within the same agroecological zone group. Here we group together i. LILC and EILI (including Africa and South Asia) and ii. HIHC and EXHC (comprising the Americas, Eurasia and Australia). EILI and EXHC have the highest labour productivity in the respective agroecological zone group and thus, the requirements remain the same as the future requirements of the already efficient systems are not presently modelled. For the very fast transition scenario (MDA_{VFST}), livestock classes are matched with the highest labour productivity cluster globally (which here corresponds to EXHC).

a

Scenario	Cropland field size classification			
Current	Very Small	Small	Medium	Large
MDA_{INCRE}	Small	Medium	Large	Large
MDA_{VFST}	Large	Large	Large	Large

b

Scenario	Livestock production system classification			
Current	LILC	EILI	EXHC	HIHC
MDA_{INCRE}	EILI	EILI	EXHC	EXHC
MDA_{VFST}	EXHC	EXHC	EXHC	EXHC

64 **Table 2 Crop production labour requirement inventory.** Values represent the labour requirement expressed in full time workers per hectare.

Field size	Country	Barley	Groundnut	Maize	Potato	Sugar beet	Rice	Sunflower	Sorghum	Soybean	Wheat	Rapeseed	Millet	Source link
large	Canada	0.00186						0.00186		0.00199	0.00199		0.00199	https://open.alberta.ca/dataset/098d9b7f-d52d-4f13-bfc6-3faccee86c53/resource/66074170-45bd-4d72-89f0-6c5f68e16979/download/af-2019-cost-return-benchmarks-crops-forages-dryland-2021-01.pdf
large	Canada			0.00169								0.00169		https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/bus15031/$file/potential-for-grain-corn-sm.pdf?OpenElement
large	Canada				0.02273									https://www.gov.mb.ca/agriculture/business-and-economics/financial-management/pubs/cop_crop_irrigatedpotato.pdf
large	Canada					0.00453								https://open.alberta.ca/publications/1927-9272
large	Italy (originally in small field size)*						0.02297							https://ec.europa.eu/agriculture/rica/pdf/sa0301_rice.pdf
medium	UK				0.02682	0.01091		0.00364				0.00382		https://www.thepocketbook.co.uk/
medium	UK, Slovakia	0.01188							0.01126				0.01126	https://ec.europa.eu/agriculture/rica/pdf/cereal_report_2013_final.pdf
medium	France		0.05161								0.01074			https://ec.europa.eu/agriculture/rica/pdf/sa0401_nuts.pdf https://ec.europa.eu/agriculture/rica/pdf/cereal_report_2013_final.pdf
medium	Spain						0.04762							https://ec.europa.eu/agriculture/rica/pdf/sa0301_rice.pdf
medium	Germany											0.00367		https://daten.ktbl.de/vrpflanze/home.action
medium	Bulgaria, Slovakia			0.01962										https://ec.europa.eu/agriculture/rica/pdf/cereal_report_2013_final.pdf
medium	Brazil									0.00541				https://wwf.panda.org/wwf_news/?73900/Facts-about-soy-production-and-the-Basel-Criteria-En-Fr-Sp-Por-De-It
small	Austria, Greece	0.02016		0.04145					0.02167		0.02113		0.02167	https://ec.europa.eu/agriculture/rica/pdf/cereal_report_2013_final.pdf

small	Austria, Greece				0.06256	0.06256								https://agridata.ec.europa.eu/extensions/DashboardFarmEconomyFocusCrops/DashboardFarmEconomyFocusCrops.html (Type of farming: Specialist other field crops)
small	Austria							0.00349				0.00345		https://idb.agrarforschung.at/default.html
small	Greece		0.18571											https://ec.europa.eu/agriculture/rica/pdf/sa0401_nuts.pdf
small	Greece, Italy, Portugal						0.06364							https://ec.europa.eu/agriculture/rica/pdf/sa0301_rice.pdf
small	Serbia									0.01332				https://www.researchgate.net/profile/Biserka-Komnenic-2/publication/312121573_The_agricultural_knowledge_and_information_system_research_and_technology_adoption_in_Serbian_agricultural_sector_pp_276-293_In_THEMATIC_PROCEEDINGS_EMERGING_TECHNOLOGIES_AND_THE_DEVELOPMENT_OF_AGRICU/links/5870251408ae6eb871bf83c4/The-agricultural-knowledge-and-information-system-research-and-technology-adoption-in-Serbian-agricultural-sector-pp-276-293-In-THEMATIC-PROCEEDINGS-EMERGING-TECHNOLOGIES-AND-THE-DEVELOPMENT-OF-AGRI.pdf#page=214
very small	India	0.18081	0.28569	0.24127	0.38782	0.38782	0.29454	0.12672	0.17355	0.14773	0.15354	0.17656	0.20798	https://eands.dacnet.nic.in/Cost_of_Cultivation.htm

* Rice labour requirement taken from Italy: although it is in the small field size class, it demonstrates the most labour productive system across EU rice farms.

Table 3 Livestock production labour requirement inventory.

Livestock Cluster Typology	Country	Dairy cattle	Meat cattle	Dairy sheep and goats	Meat sheep and goats	Pig	Meat Poultry	Eggs poultry	Source link
HIHC	UK	0.015	0.005		0.00182	0.00091	0.00002	0.00006	https://www.thepocketbook.co.uk/
HIHC	Spain			0.004					https://www.sciencedirect.com/science/article/pii/S0022030214004342
EXHC	Australia	0.010	0.002		0.00065	0.00025	0.000016	0.00004	https://www.agriculture.gov.au/abares/research-topics/surveys/farm-survey-data
EXHC	China	0.144	0.047		0.01975	0.00699	0.00013	0.00053	http://www.stats.gov.cn/tjsj/tjcbw/202008/t20200824_1785455.html
EILI	Syria				0.02359				https://www.sciencedirect.com/science/article/pii/S0921448810000842
EILI	Pakistan						0.00006		https://www.sciencedirect.com/science/article/pii/S1658077X17302497

EILI	Vietnam					0.02			http://www.tandfonline.com/doi/abs/10.1080/08974430802157606
EILI	Thailand							0.00002	https://www.semanticscholar.org/paper/Production-Efficiency-of-Broiler-Farming-in-A-Todsadee-Kameyama/114d7cb990c31f21f124a42f2bfae82405db3fbe
EILI	South Africa	0.07266							http://www.tandfonline.com/doi/abs/10.1080/03031851003798686
EILI	South Africa	0.0509							https://link.springer.com/article/10.1007/s11250-008-9288-1
LILC	Nigeria							0.00027	https://www.journalajaees.com/index.php/AJAEES/article/view/28237
LILC	Nigeria					0.0150			https://www.academia.edu/download/63239020/IJRR005020200508-92321-192u2bq.pdf
LILC	Nigeria		0.07576						https://www.researchgate.net/profile/Oluwafunmiso-Adeola-Olajide/publication/314031261_Technical_efficiency_of_beef_cattle_production_technologies_in_Nigeria_A_stochastic_frontier_analysis/links/5c8a17a592851c1df9401dd1/Technical-efficiency-of-beef-cattle-production-technologies-in-Nigeria-A-stochastic-frontier-analysis.pdf
LILC	Bangladesh						0.00094		https://doi.org/10.1080/00036846.2011.581216
LILC	Ghana				0.075968				https://www.sciencedirect.com/science/article/pii/S1871141317300896#bib51
LILC	Uganda	0.04855							https://www.scirp.org/html/5-7201029_58393.htm?pagespeed=noscript
LILC	Botswana		0.03421						https://www.tandfonline.com/doi/pdf/10.1080/03768350802212121

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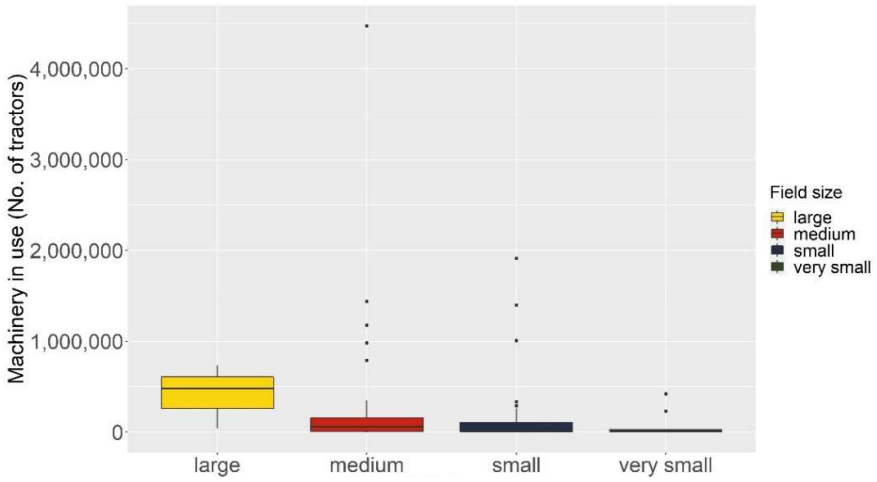
Figures

Fig. 1 Relationship between cropland field size and a. technological adoption (measured by number of tractors in use), b. GDP per capita in current US dollars.

a



b

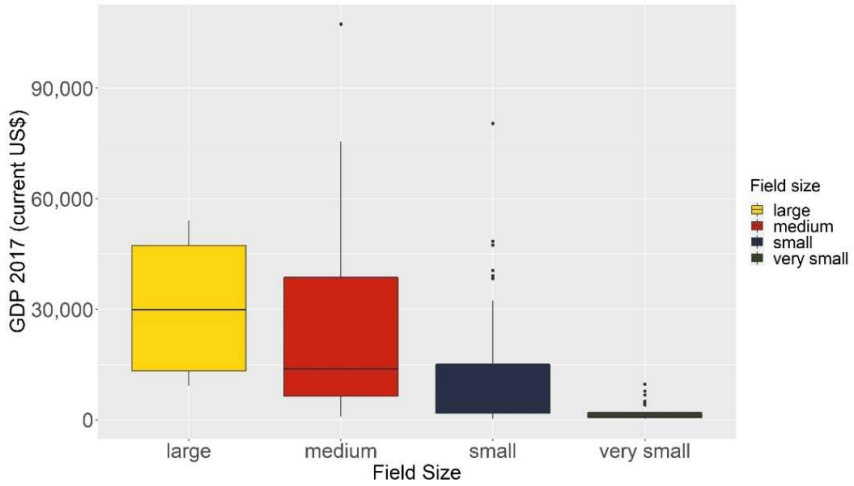


Fig. 2 Agricultural workers per hectare of cropland by field size class. Data points represent the different countries and the corresponding number of people employed in agriculture (ILOSTAT) per hectare of cropland (FAOSTAT) for the year 2013.

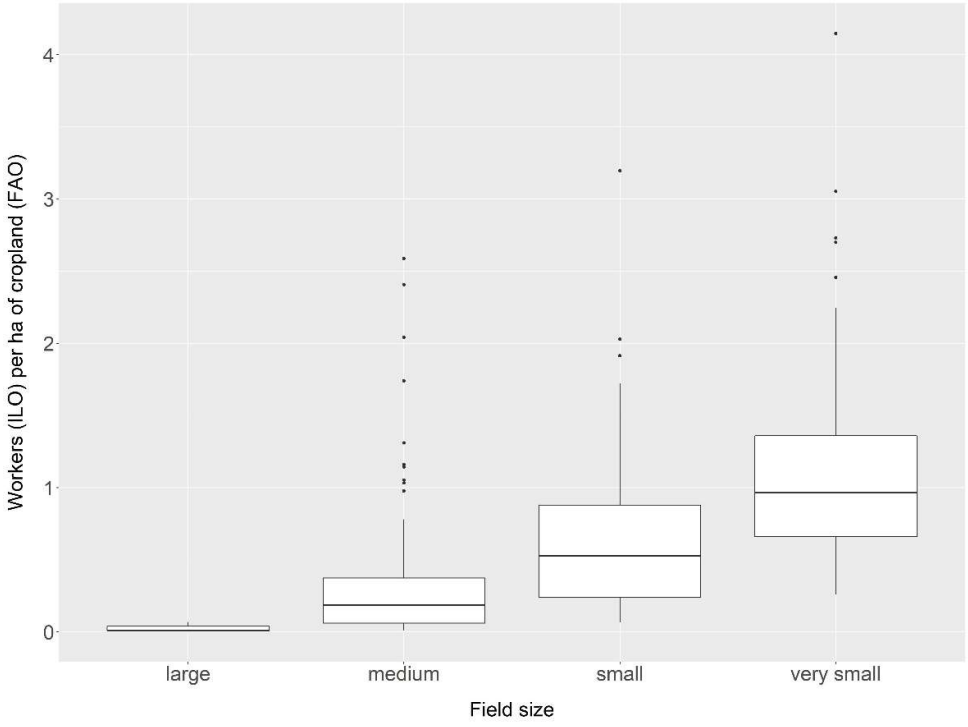


Fig. 3 Livestock systems cluster typology. Clustering of countries based on similar attributes relating to the role of livestock, society and the country's economy (adopted from Herrero et al. 2020). The four global livestock system clusters include: (i) high income countries with high inputs of production and high levels of consumption (HIHC); (ii) low- and middle-income countries with low inputs of production and low levels of productivity and consumption (LILC); (iii) low-, middle- and high-income countries with higher livestock consumption and extensive grazing areas (EXHC); and (iv) low- and middle-income countries with varying livestock consumption and emerging importance of livestock (EILI).

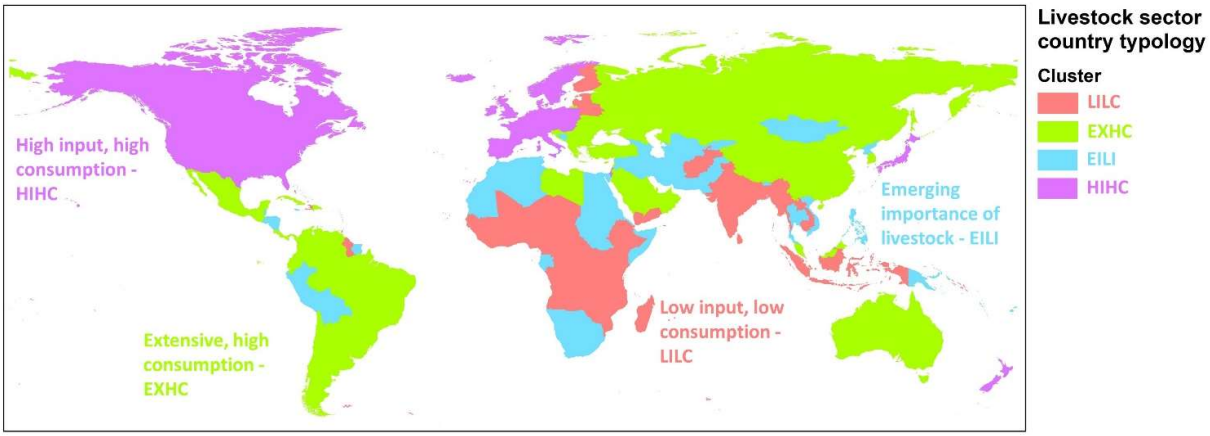
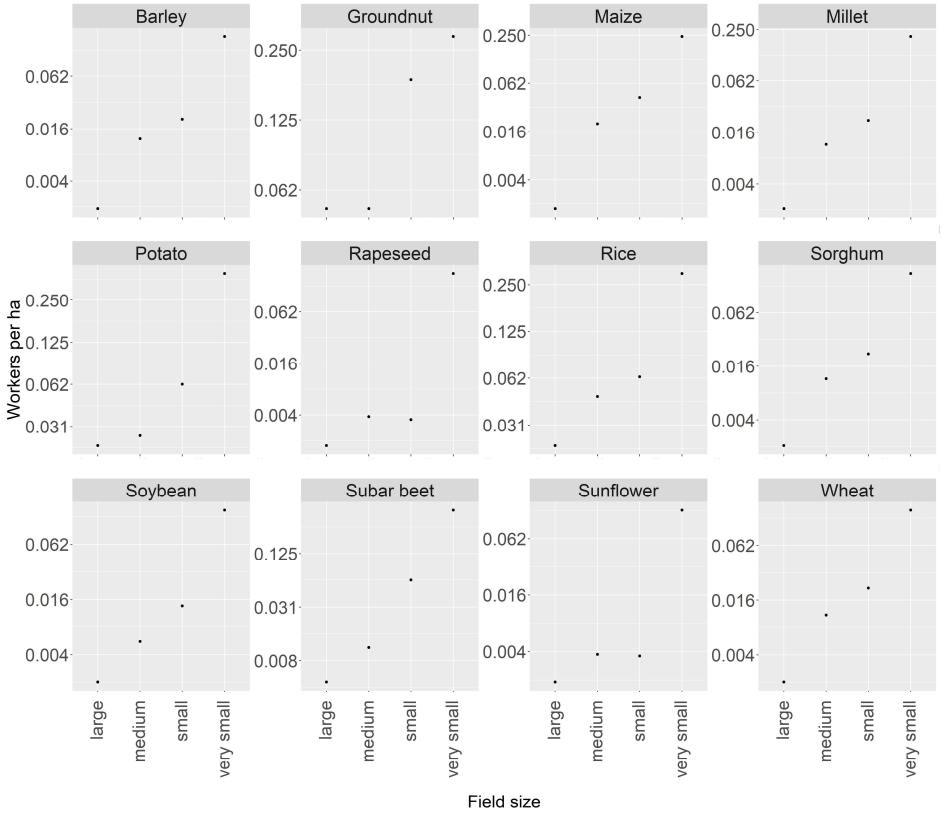


Fig. 4 Labour requirements a. for crop production (workers per hectare) by crop and field size class and b. for livestock production (workers per head) by livestock type and livestock system cluster. These values are the aggregate (mean) labour requirements reported in the labour inventory (Table 1 and Table 2 above).

a



b

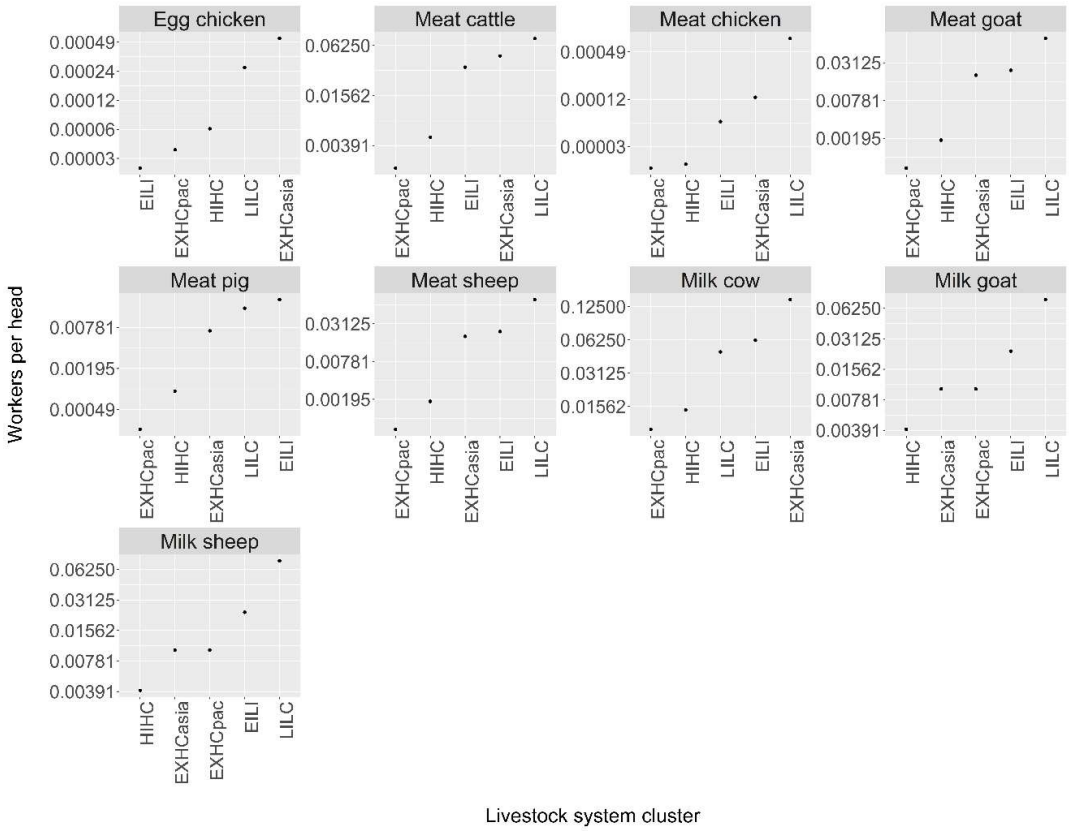


Fig. 5 Graphical representation of the relationship between field size, level of mechanisation and corresponding labour requirements in a. current state of agricultural labour and b. the pathway of this relationship following the mechanisation development potentials (Incremental and Very fast) across very small field size production systems.

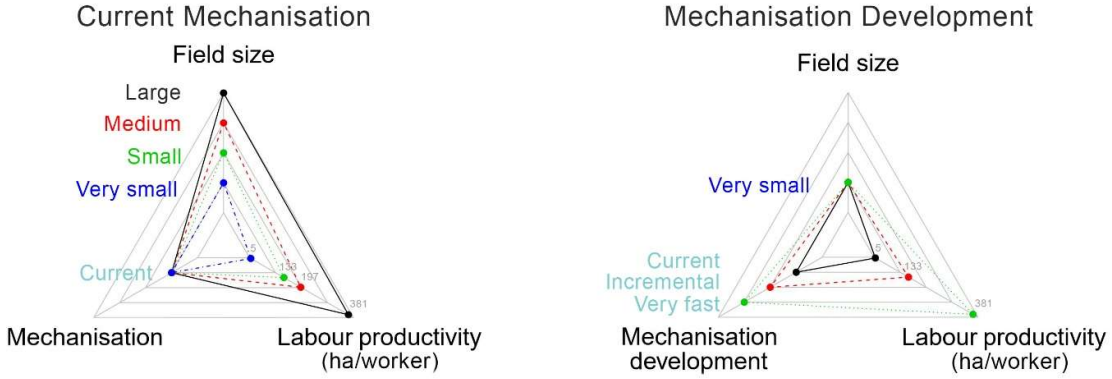


Fig. 6 Total labour requirements (AWU) in the current and future agricultural mechanisation scenarios. The facet on the right-hand side demonstrates the stacked bars of labour requirements in AWU in the current state of agricultural labour and the two static scenarios agricultural mechanisation development. The left-hand side displays in more detail the labour requirements in for the two static scenarios of structural change.

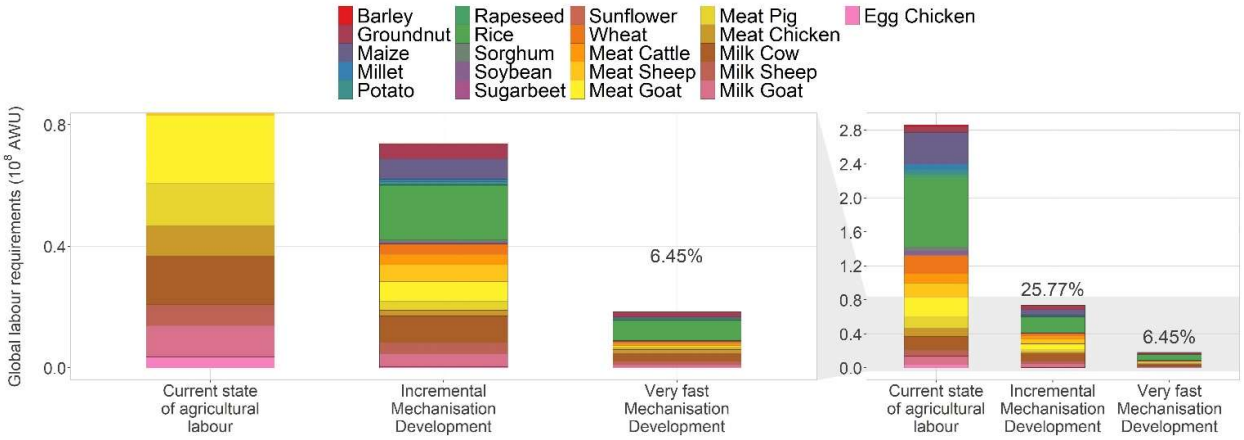


Fig. 7 Rate of change in labour requirements in the current and future agricultural mechanisation scenarios.

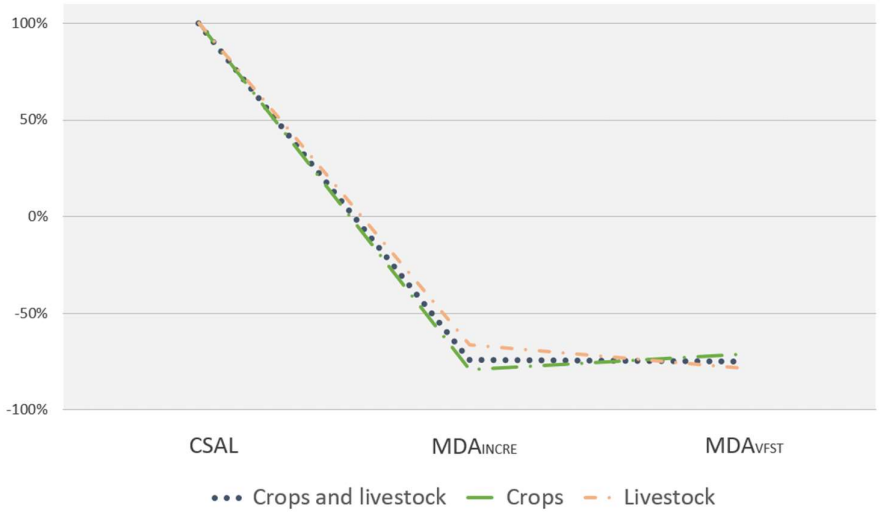


Fig. 8 Fraction of potential agricultural labour release in each spatial pixel between current, incremental change and very fast transition of systems mechanisation.

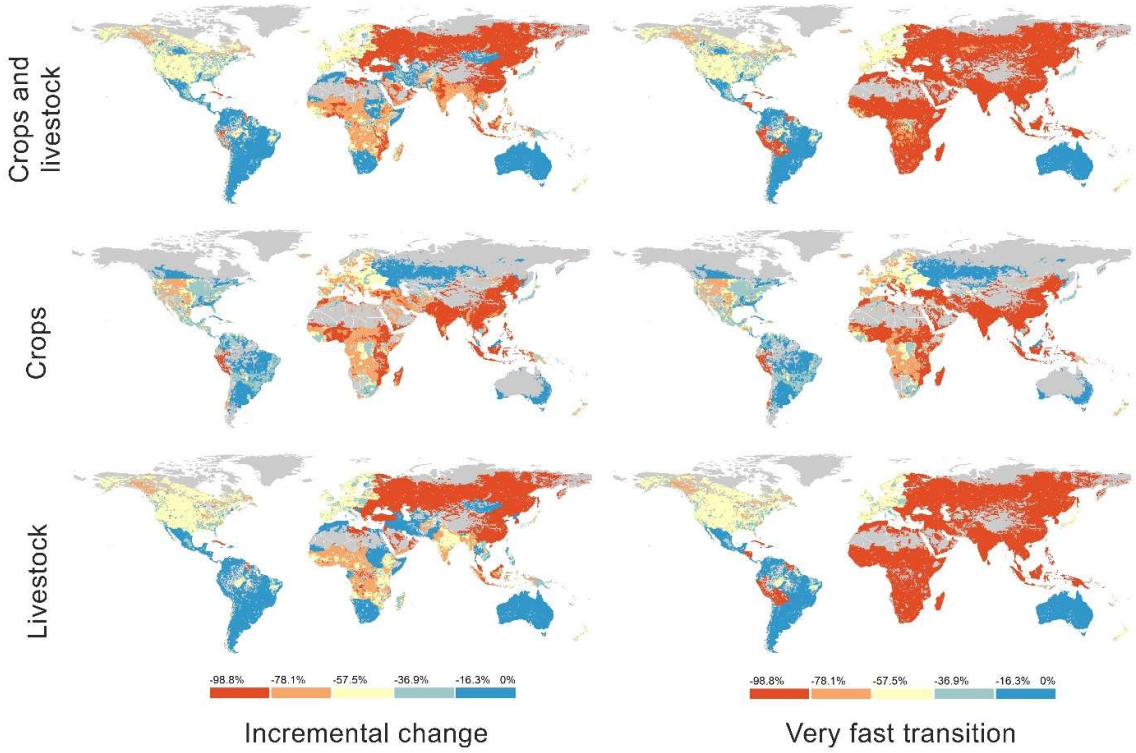


Fig. 9 Calorie production per agricultural worker (Mcal per AWU) in the current state of agricultural sector (CSAL) and the two what-if scenarios of mechanisation development (MDA_{INCRE} and MDA_{VFST}).

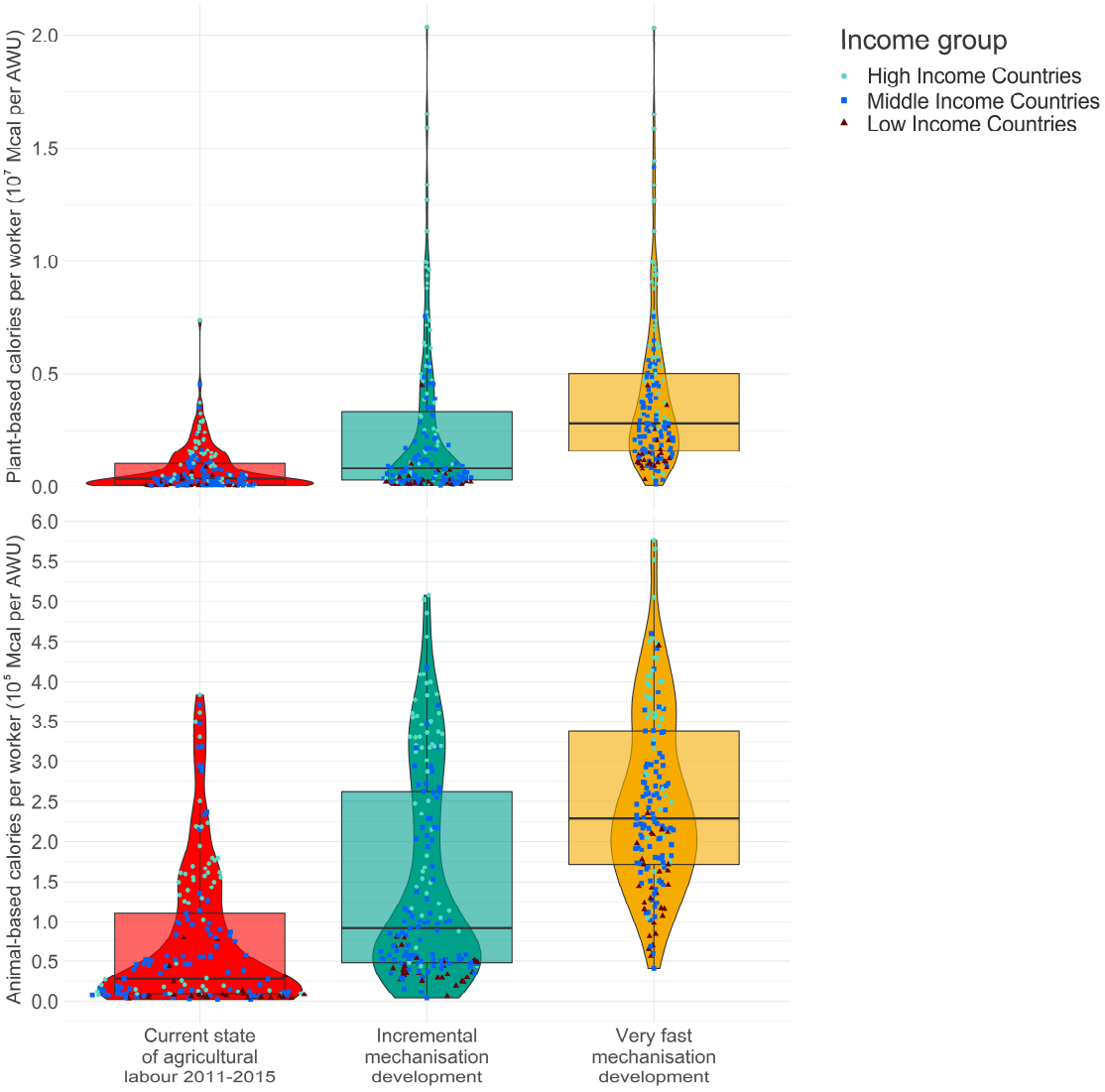


Fig. 10 Protein production per agricultural worker (tonnes of protein per AWU) in the current state of agricultural sector (CSAL) and the two what-if scenarios of mechanisation development (MDA_{INCRE} and MDA_{VFST}).

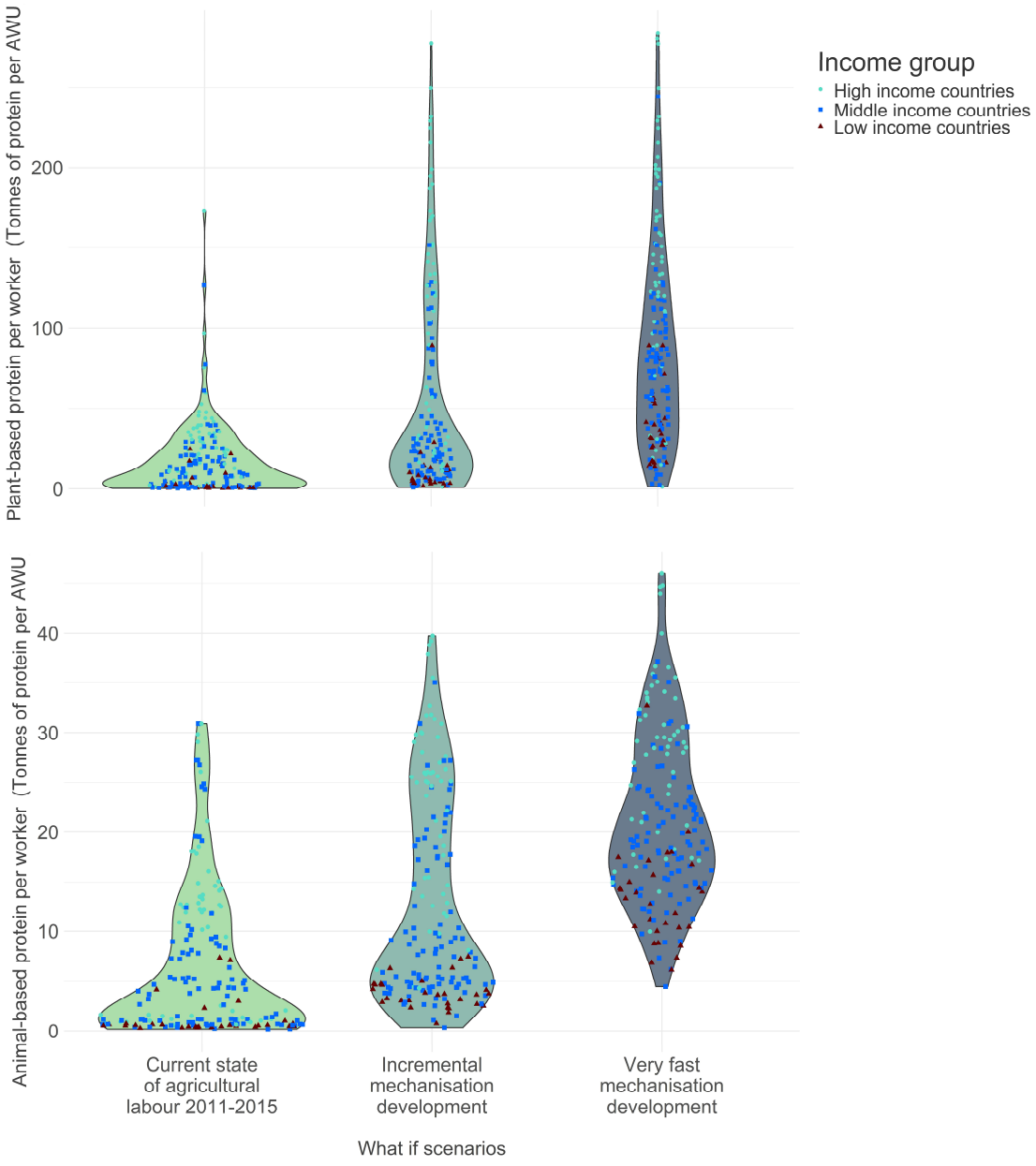


Fig. 11 Evaluation of modelled labour requirement for cereal production (measured in AWU) against reported FADN labour inputs.

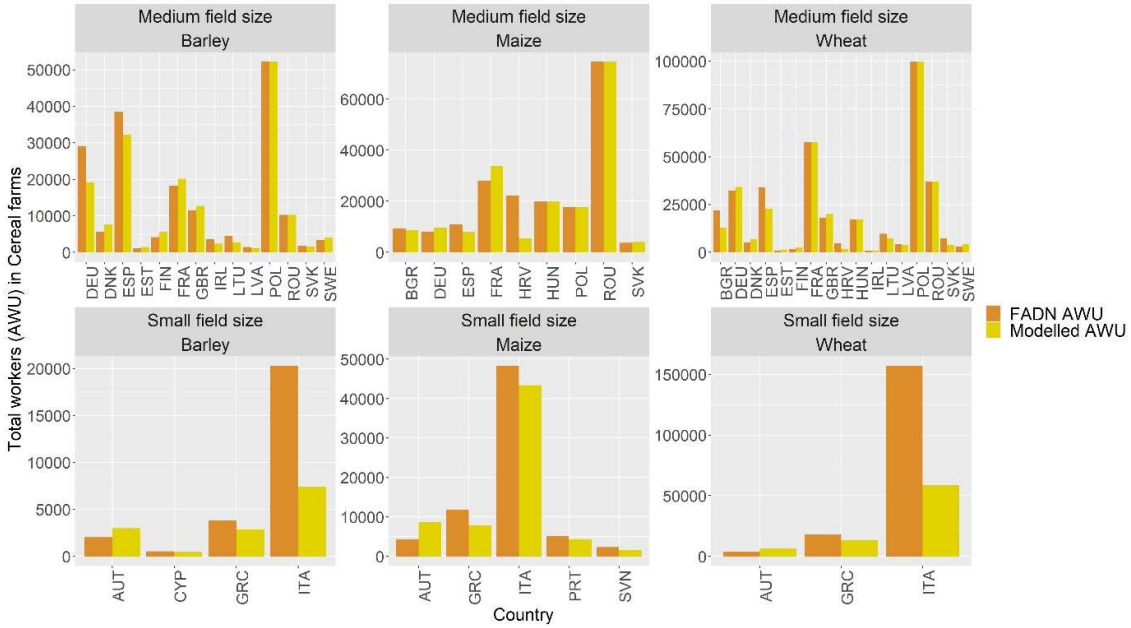


Fig. 12 Evaluation of modelled labour requirement for cattle meat production (measured in AWU) against reported FADN labour inputs.

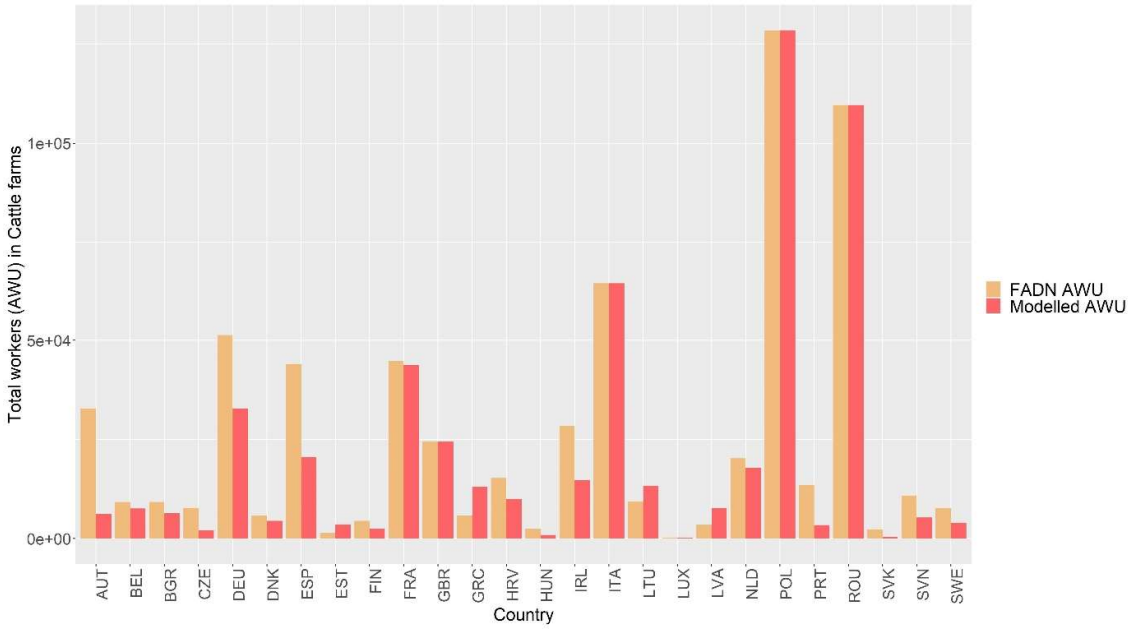
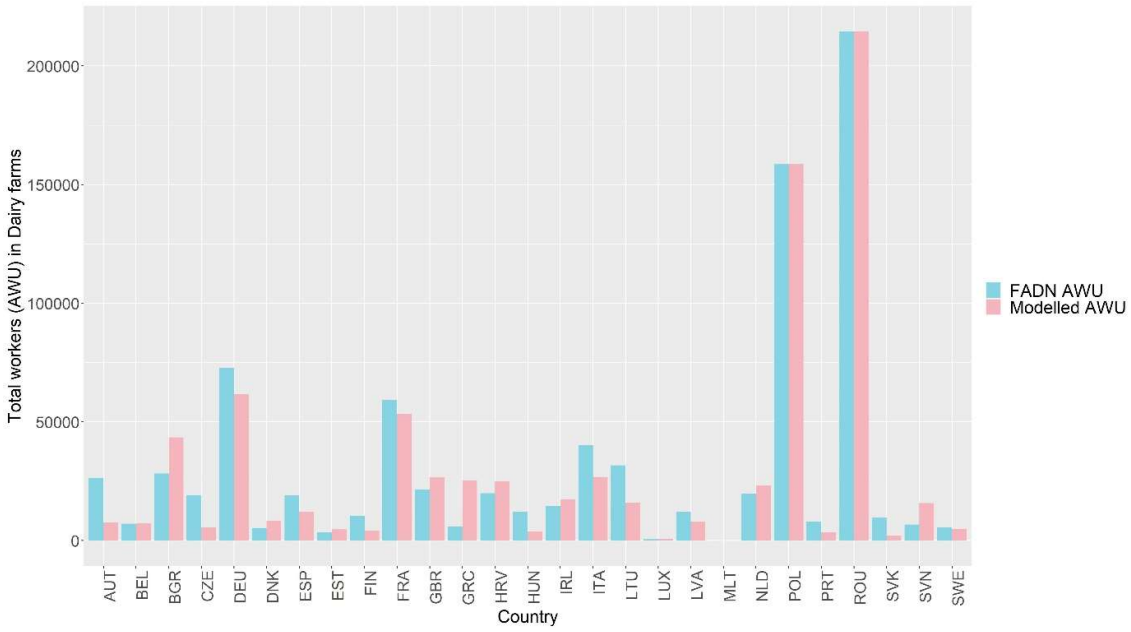


Fig. 13 Evaluation of modelled labour requirement for cow's milk production (measured in AWU) against reported FADN labour inputs.

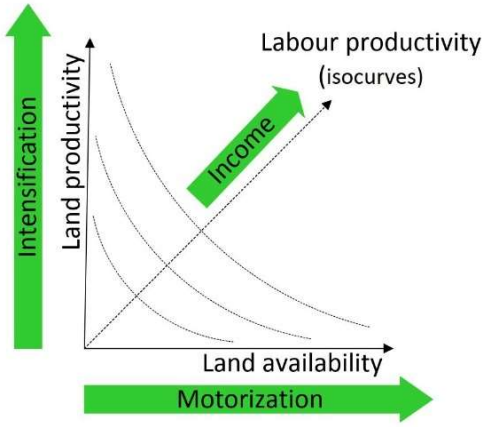


Texts

Supplementary Text 1

Developments in technological and labour productivity reflect already visible trends in global agricultural systems and go along differences in incomes and industrialisation[1]. Labour productivity (iso-curves) (hectares per agricultural worker – ha/worker) can be stimulated by a simultaneous increase of land productivity (production per unit of land – tonnes/ha) and land availability (hectares of cultivated land per agricultural worker – ha/worker) (Supplementary material, Fig. 14)[2]. Increased land productivity is achieved through intensification with higher production resulting from sufficient irrigation and fertilizers and greater land availability represents larger area of cultivated land per worker through "motorization" in which motors replace human and animal energy for the production processes (plough, spray, harvest etc.)[2]. In our baseline classification we identify very similar patterns of labour requirements in which lower technological adoption and land availability (here reflected by fewer motorised machineries, and smaller field sizes) relates to larger numbers of labourers required across poorer countries, and vice versa across richer countries (Supplementary material, Fig. 1 and Fig. 2). The latter provides support to the labour requirement inventory that we compile here as we identify the same trends linking land availability, technological adoption and labour productivity (Supplementary material, Fig. 4, Table 2 and Table 3).

Fig. 14 Labour productivity pathways (Figure adopted from Dorin et al. 2013, "A World without Farmers? The Lewis Path Revisited")**.**



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1. A World without Farmer? Food Production, Inclusive Development and Ecology: Historical Evidences for a New Deal (1961-2007). *Ecological Economics* **143**, 324–325 (2012).
2. Dorin, B., Hourcade, J. C. & Benoit-Cattin, M. A World without Farmers ? The Lewis Path Revisited. (2013).