

Supplementary Materials

Global Land Use Impacts of Bioeconomy: An Econometric Input–Output Approach

Johannes Reinhard Többen ^{1,2*}, Martin Distelkamp ¹, Britta Stöver ¹, Saskia Reuschel ¹, Lara Ahmann ¹ and Christian Lutz ¹

¹ Gesellschaft für Wirtschaftliche Strukturforchung (GWS) mbH, Osnabrück, Germany; toebben@gws-ows.com (J.T.); distelkamp@gws-os.com (M.D.); stoever@gws-os.com (B.S.); reuschel@gws-os.com (S.R.); ahmann@gws-os.com (L.A.); lutz@gws-os.com (C.L.)

² Social Metabolism & Impacts, Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Potsdam, Germany; toebben@gws-os.com (J.T.)

* Correspondence: toebben@gws-os.com

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Table S1. Crops and livestock products distinguished in the agriculture module.

Crops		Livestock Products	
1	Wheat	1	Cattle and buffalo meat
2	Maize	2	Pig meat
3	Rice	3	Poultry meat
4	Other cereals	4	Other meat
5	Grapes	5	Milk
6	Other fruits	6	Eggs
7	Soybeans	7	Wool and silk
8	Rapeseed and mustard seed	8	Honey and beeswax
9	Palm fruit oil		
10	Other oil crops		
11	Pulses		
12	Spices		
13	Potatoes		
14	Other starchy roots		
15	Stimulants		
16	Sugar crops		
17	Tree nuts		
18	Onions and tomatoes		
19	Other vegetables		
20	Fibers		

Source: own elaboration.

Table S2. Mid-layer coefficients of the agriculture module.

Aggregate Commodity Basket	Use Category	$\log(\alpha)$	$\log(fx)$	$\beta_1 \log(v_1)$	$\beta_2 \log(v_2)$	$\gamma \log(\text{price})$	R ²	Info
Basic food crops	Food use	4.073 ***	−1 ***	0.242 ***	−0.016 ***		0.950	v1 = total domestic price-deflated per capita demand, agriculture v2 = v1 * price
	Feed use	−0.398 ***	−1.01 ***	1.017 ***	0.051 ***	−0.335 ***	0.960	v1 = total weighted production quantity primary livestock v2 = share of pig meat in total production quantity primary livestock
Feed and food cereals	Food use	−2.529 ***	−1.005 ***	0.934 ***		−0.445 ***	0.977	v1 = use of basic food crops
	Processing and other non-food	4.104 ***	−1.072 ***	0.393 ***		−0.381 ***	0.876	v1 = price-deflated use of agricultural products in manufacture of petroleum products, chemical products and rubber and plastic products
Fruits and vegetables	Food use	4.377 ***	−1.001 ***	0.212 ***		−0.227 ***	0.964	v1 = total domestic price-deflated per capita demand, agriculture
	Feed use	−3.324 ***	−1.001 ***	0.939 ***	0.08 **	−0.23 ***	0.828	v1 = total weighted production quantity primary livestock v2 = share of pig meat in total production quantity primary livestock
Oil crops	Food use	−2.194 ***	−1.009 ***	0.96 ***		−0.385 ***	0.973	v1 = use of basic food crops
	Processing and other non-food	5.171 ***	−1.063 ***	0.612 ***		−0.619 ***	0.900	v1 = price-deflated use of agricultural products in manufacture of petroleum products, chemical products and rubber and plastic products
Sugar crops	Processing and other non-food	−1.041 ***	−1.038 ***	0.689 ***		−0.711 ***	0.903	v1 = price-deflated use of agricultural products in manufacture of petroleum products, chemical products and rubber and plastic products

Fiber crops	Processing and other non-food	1.679 ***	−1.09 ***	0.72 ***		−0.623 ***	0.876	v1 = price-deflated use of agricultural products in manufacture of textiles and clothing apparel
Spices, stimulants and nuts	Food use	1.445 ***	−1 ***	0.306 ***		−0.38 ***	0.912	v1 = total domestic price-deflated per capita demand, agriculture
Meat	Food use	1.841 ***	−1 ***	0.594 ***	−0.017 ***	−0.369 ***	0.976	v1 = total domestic price-deflated per capita demand, agriculture v2 = v1 * price
Milk	Food use	−1.764 ***	−1 ***	1.148 ***	−0.084 ***		0.987	v1 = total domestic price-deflated per capita demand, agriculture v2 = v1 * price
Eggs	Food use	2.132 ***	−1 ***	0.121 ***		−0.153 ***	0.908	v1 = total domestic price-deflated per capita demand, agriculture

Source: own calculations, *p*-value: < 0.1, * <0.05, ** <0.01, *** <0.001.

Table S3. Bottom-layer coefficients of the agriculture module.

Aggregate Commodity Basket	Crops	log(α)	log(f_x)	γ log(price)	R ²
Basic food crops	Wheat	−1.149 ***	−1.001 ***	−0.446 ***	0.933
	Rice	−2.27 ***	−1.033 ***	−1.09 ***	0.911
	Pulses	−3.679 ***	−1 ***	−0.259 ***	0.776
	Potatoes	−1.883 ***	−1.015 ***	−0.787 ***	0.947
	Other starchy roots	−4.559 ***	−1.014 ***	−1.912 ***	0.902
Feed and food cereals	Maize	−0.896 ***	−1.052 ***	−1.674 ***	0.890
	Other cereals	−1.448 ***	−1.073 ***	−1.125 ***	0.891
Fruits and vegetables	Grapes	−2.702 ***	−1.055 ***	−1.148 ***	0.890
	Other fruits	−0.846 ***	−1 ***	−0.018 **	0.884
	Onions and tomatoes	−2.214 ***	−1 ***	−0.191 ***	0.953
	Other vegetables	−1.221 ***	−1.002 ***	−0.189 ***	0.926
Oil crops	Soybeans	−1.168 ***	−1.004 ***	−0.593 ***	0.794
	Rapeseed and mustard seed	−3.071 ***	−1.036 ***	−1.1 ***	0.837
	Palm fruit oil	−2.153 ***	−1.001 ***	−0.23 ***	0.793
	Other oil crops	−1.34 ***	−1.008 ***	−0.77 ***	0.841
Spices, stimulants and nuts	Spices	−2.415 ***	−1.004 ***	−0.4 ***	0.845
	Stimulants	−0.488 ***	−1.001 ***	−0.158 ***	0.863
	Tree nuts	−2.282 ***	−1.007 ***	−0.425 ***	0.890
Meat	Cattle and buffalo meat	−1.456 ***	−1.003 ***	−0.902 ***	0.941
	Pig meat	−1.566 ***	−1 ***	−0.509 ***	0.970
	Poultry meat	−1.322 ***	−1.004 ***	−0.462 ***	0.818
	Other meat	−3.437 ***	−1.005 ***	−0.094 ***	0.942

Source: own calculations, p -value: <0.1, * <0.05, ** <0.01, *** <0.001.

Table S4. Estimation results of the structural gravity model.

	Crops	log(dist)		lang = 1		lang = 0		same_cou = 1		R ² (McFadden)
1	Wheat	−1.28 ***		8.74 ***		9.21 ***		3.71 ***		0.992
2	Maize	−1.65 ***		9.73 ***		9.92 ***		5.35 ***		0.994
3	Rice	−1.61 ***		3.75		3.52		4.99 ***		0.998
4	Other cereals	−1.49 ***		1.07 ***		1.03 ***		3.69 ***		0.991
5	Grapes	−1.12 ***		6.85 ***		6.59 ***		4.37 ***		0.993
6	Other fruits	−1.35 ***		10.01 ***		9.84 ***		3.17 ***		0.991
7	Soybeans	−1.09 ***		4.34 *		4.67		4.32 ***		0.991
8	Rapeseed and mustard seed	−1.37 ***		7.82 ***		8.68 ***		3.74 ***		0.985
9	Palm fruit oil	−6.63 ***		1.39		1.37		4.31 ***		0.995
10	Other oil crops	−1.19 ***		6.75 ***		5.64 ***		3.72 ***		0.995
11	Pulses	−0.82 ***		4.91 ***		4.34 ***		3.86 ***		0.991
12	Spices	−0.81 ***		2.81 ***		2.62 ***		2.89 ***		0.973
13	Potatoes	−1.02 ***		7.82 ***		6.91 ***		3.48 ***		0.999
14	Other starchy roots	−1.64 **		2.41		1.37		4.75 ***		0.999
15	Stimulants	−7.95 ***		5.04 ***		4.61 ***		2.83 ***		0.971

16	Sugar crops	−2.32		1.27		1.26		6.16		0.999
17	Tree nuts	−1.06	***	4.81	***	4.38	***	3.01	***	0.987
18	Onions and tomatoes	−1.41	***	8.25	***	7.91	***	3.48	***	0.995
19	Other vegetables	−1.76	***	1.11	***	1.06	***	3.36	***	0.998
20	Fibers	−0.74	***	1.71	*	1.83	.	4.81	***	0.995
21	Cattle and buffalo meat	−7.05	***	3.72	***	3.79	***	4.68	***	0.996
22	Pig meat	−1.58	***	6.95	***	6.71	***	4.25	***	0.997
23	Poultry meat	−1.05	***	5.87	***	5.86	***	3.94	***	0.992
24	Other meat	−0.86	***	3.71	***	2.35	***	3.14	***	0.983
25	Milk	−0.85	***	7.37	***	6.43	***	4.61	***	0.999
26	Eggs	−1.51	***	7.45	***	7.88	***	4.22	***	0.998
27	Wool and silk	−0.98	***	−3.41		−8.21		3.56	***	0.981
28	Honey and beeswax	−0.78	***	2.91	***	2.52	***	3.13	***	0.939

Source: own elaboration, *p*-value: <0.1, * <0.05, ** <0.01, *** <0.001.

Table S5. Estimation results of the exporter fixed effects.

	Estimate	Std. Error	t Value	Pr(> t)
log(YIELD_REL)	0.355189	0.062832	5.653	1.61×10^{-8} ***
log(PRDP/100)	−0.173228	0.057888	2.992	0.002772 **
TIME	0.031654	0.003681	8.600	$<2 \times 10^{-16}$ ***

Residual standard error: 0.9997 on 14,468 degrees of freedom; multiple R-squared: 0.9048, adjusted R-squared: 0.8953; F-statistic: 94.53 on 1455 and 14,468 Dfs, *p*-value: $<2.2 \times 10^{-16}$. Source: own calculations, *p*-value: <0.1, * <0.05, ** <0.01, *** <0.001.

Table S6. Estimation results of the importer fixed effects.

	Estimate	Std. Error	t Value	Pr(> t)
log(QD)	6.938×10^{-1}	1.774×10^{-2}	39.102	$<2 \times 10^{-16}$ ***

Residual standard error: 0.9277 on 16,479 degrees of freedom; multiple R-squared: 0.8763, adjusted R-squared: 0.8633; F-statistic: 67.66 on 1725 and 16,479 Dfs, *p*-value: $<2.2 \times 10^{-16}$. Source: own calculations, *p*-value: <0.1, * <0.05, ** <0.01, *** <0.001.

Table S7. List of countries and country groups used in the model.

Country Group	Countries
Africa	Morocco, Tunisia, South Africa
Asia and Pacific	Australia, Brunei, Cambodia, Indonesia, Israel, Japan, Kazakhstan, Korea, Malaysia, New Zealand, the Philippines, Saudi Arabia, Singapore, Thailand
Brazil	Brazil
China	China, Chinese Taipei, Hong Kong
Europe	Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom
India	India
North America	Canada, Costa Rica, Mexico, United States
Russia	The Russian Federation
South America	Argentina, Chile, Peru

Table S8. Area harvested for crops in million hectares for 2017 and 2040 (including absolute and relative differences between the bioeconomy and reference scenarios).

Country Groups	2017	Reference 2040	Bioeconomy 2040	Absolute Difference	Relative Difference
Africa	21	22	23	2	7.3%
Asia and Pacific	138	173	267	93	53.9%
Brazil	61	54	64	10	18.9%
China	216	204	263	59	28.7%
Europe	117	94	108	14	14.8%
India	191	175	186	11	6.1%
North America	123	108	134	26	23.7%
Russia	42	35	35	1	2.0%
South America	24	24	37	13	52.9%

Table S9. GDP per capita for 2017, 2030 and 2040 (including absolute and relative differences between bioeconomy and reference scenarios).

Country Groups	2017	Reference	Bioeconomy	Absolute Difference	Relative Difference	Reference	Bioeconomy	Absolute Difference	Relative Difference
	2030					2040			
Africa	5803	7476	7470	−6	−0.1%	9769	9762	−6	−0.1%
Asia and Pacific	14,778	21,003	21,095	91	0.4%	27,203	27,471	269	1.0%
Brazil	10,944	15,752	15,720	−33	−0.2%	20,227	20,164	−62	−0.3%
China	7503	14,604	14,603	−1	0.0%	19,774	19,787	14	0.1%
Europe	28,750	35,380	35,403	23	0.1%	41,820	41,875	55	0.1%
India	1913	3911	3898	−13	−0.3%	5922	5903	−18	−0.3%
North America	41,684	51,520	51,621	101	0.2%	61,241	61,456	215	0.4%
Russia	7267	9515	9499	−16	−0.2%	11,857	11,829	−28	−0.2%
South America	8904	9935	9964	29	0.3%	11,002	11,033	30	0.3%

Table S10. Percentage difference between the bioeconomy and reference scenarios for 2030 and 2040 for different aggregate production sectors and country groups.

Production Sectors	Africa	Asia and Pacific	Brazil	China	Europe	India	North America	Russia	South America
2030									
Agriculture	−1.1	25.1	−4.3	4.3	1.2	−0.9	0.4	−0.1	−0.3
Coke	−0.1	0.5	−0.2	0.0	−0.3	−0.2	0.0	−0.4	−0.1
Electricity	−0.1	0.7	0.0	0.2	0.1	−0.3	0.0	−0.1	0.0
Food	−0.4	6.1	−2.0	0.9	0.6	−1.0	0.2	−0.1	0.3
Mining	−0.2	0.1	0.0	−0.1	2.8	−0.6	−0.2	−0.4	0.2
Other industries	−0.1	0.4	−0.4	0.0	0.1	−0.5	0.0	−0.1	−0.1
Other services	−0.1	0.0	−0.3	0.0	0.1	−0.2	0.0	−0.2	−0.1
Transportation	−0.1	−0.5	−0.3	0.0	0.1	−0.2	0.0	−0.2	−0.1
2040									
Agriculture	−1.6	36.2	−5.5	6.9	1.2	−1.2	−0.3	−0.2	−0.3
Coke	−0.1	1.3	−0.2	0.1	−0.8	−0.1	0.1	−0.6	0.0

Electricity	−0.1	1.5	−0.1	0.5	0.2	−0.2	0.0	0.0	0.0
Food	−0.4	4.6	−2.4	1.1	0.6	−0.9	0.2	0.0	0.3
Mining	0.0	0.7	−0.5	0.1	0.4	−0.1	−0.4	−2.4	0.9
Other industries	−0.1	0.2	−0.4	0.1	0.2	−0.4	0.0	−0.1	0.0
Other services	−0.1	−0.4	−0.4	0.1	0.2	−0.1	0.0	−0.2	−0.1
Transportation	0.0	−1.0	−0.2	0.1	0.2	−0.1	0.0	−0.2	−0.1

Agriculture: Agriculture, forestry and fishing; Coke: Coke, refined petroleum, chemicals and pharmaceutical products; Electricity: Electricity, gas, water supply sewerage, waste and remediation services; Food: Food products, beverages and tobacco; Mining: Mining and extraction of energy producing products; Transportation: Transportation and storage.

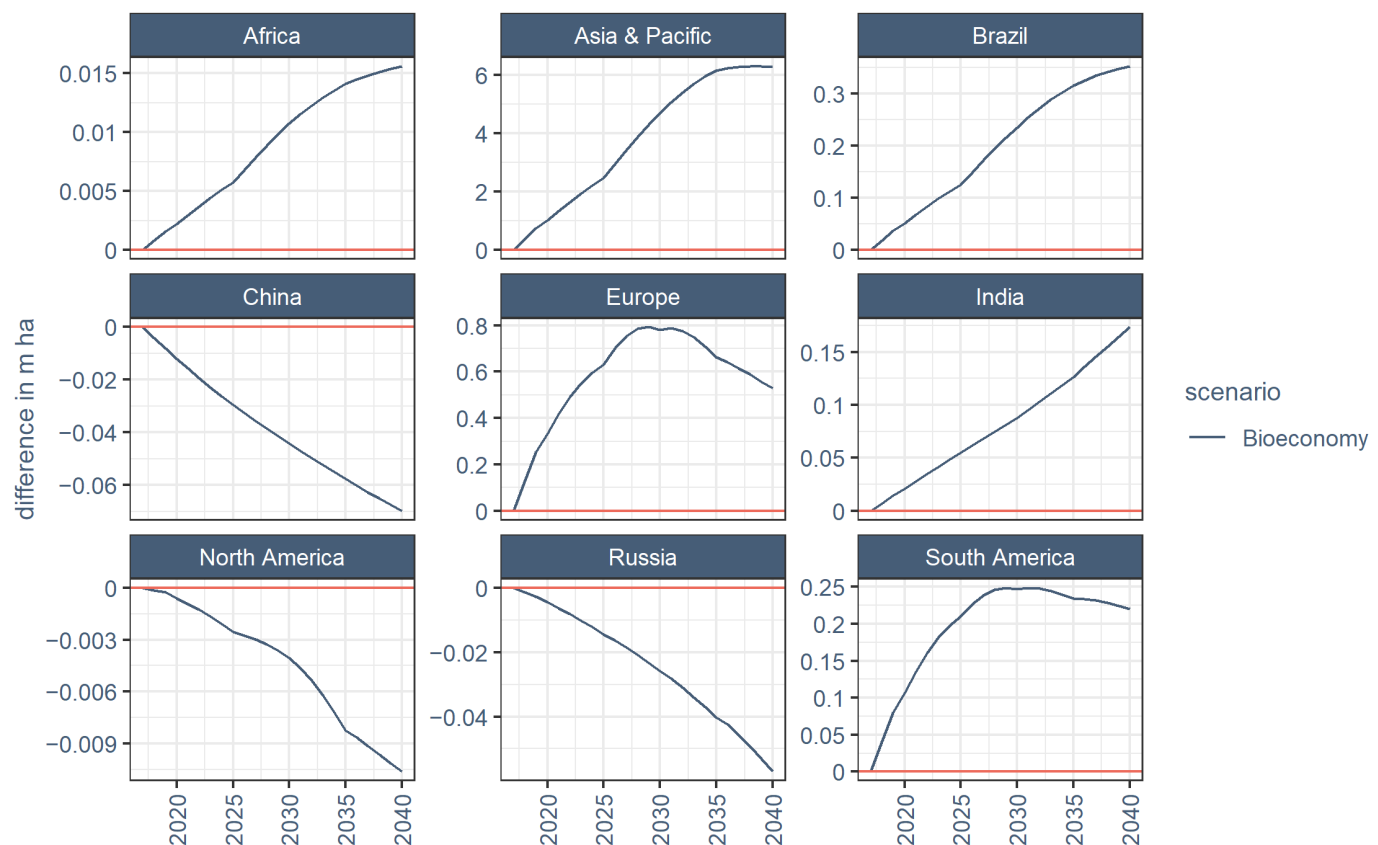


Figure S1. Absolute difference in area harvested for sugar between the reference and bioeconomy scenarios in million hectares.

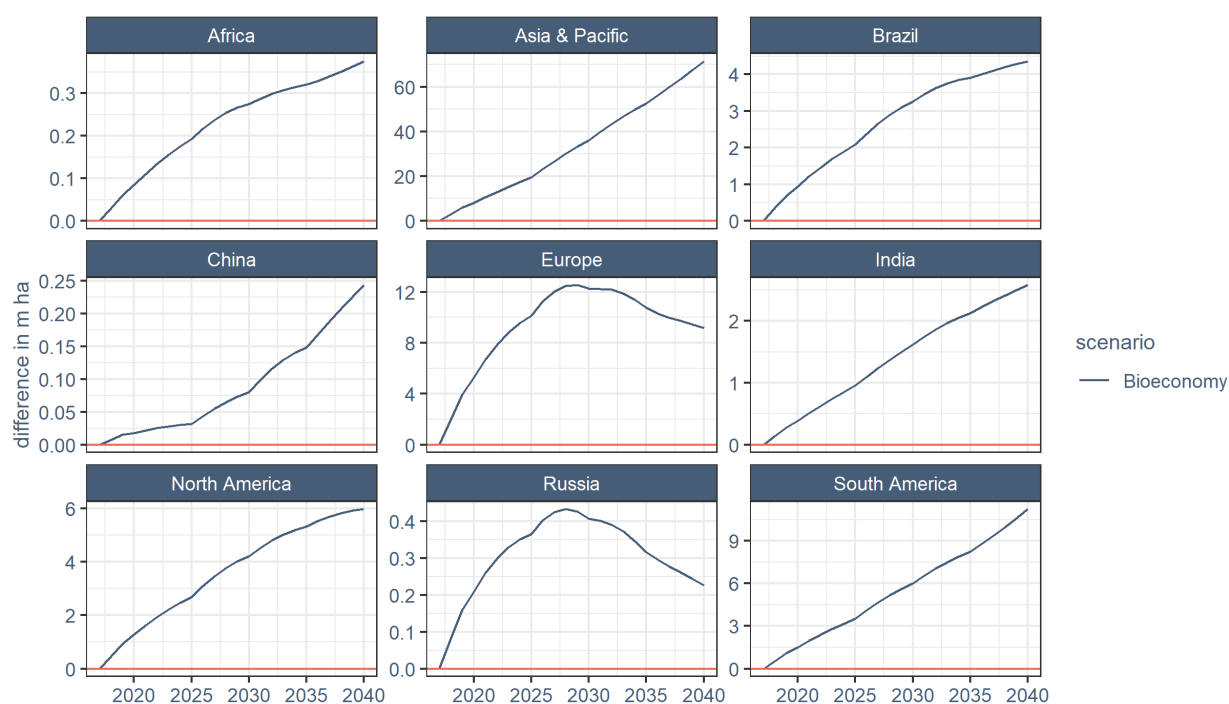


Figure S2. Absolute difference in area harvested for oleiferous fruits between the reference and bioeconomy scenarios in million hectares.

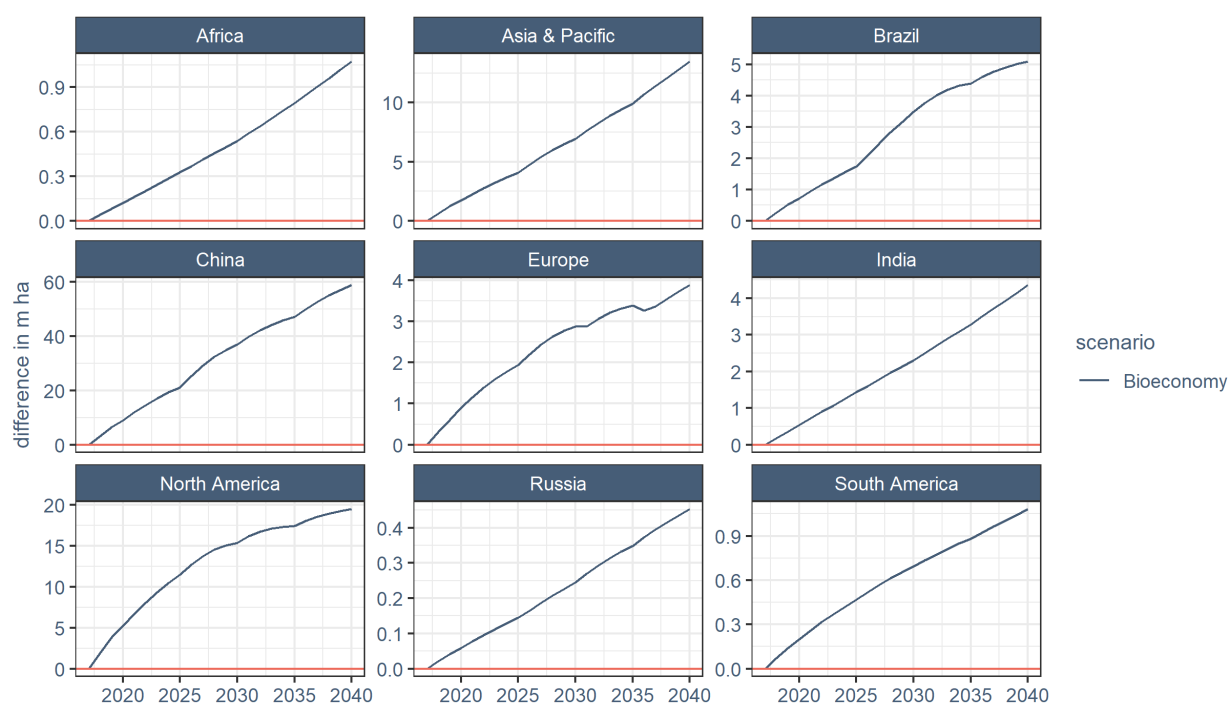


Figure S3. Absolute difference in area harvested for grains between the reference and bioeconomy scenarios in million hectares.