Evaluation of current green and blue water requirements based on global food trade balance

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Background

- Food production is necessary to sustain human social activity.

- Agricultural sector accounts for 70 % (2,658 km^3) of global water use [1].

- Direct transportation of water resources cannot be implemented.

- **Problems**

- In poor-resource countries, they have to depend on food trade to meet their domestic demand, and could increase virtual water consumption unintentionally .

- Expanding food trade could promote the gap of water consumption between producing and consuming region, and could cause water supply and demand imbalance.

Evaluating water supply-demand balance based on food balance is important.

Objective

● Main finding of our previous study [2)]

・ In several countries, food export should enhance water stress.

● Future plans of our previous study [2)]

1) Food supply and demand imbalance by lacking of supply-side analysis.

2) Underestimation of water requirement by not considering green water consumption.

● **Objective**

To evaluate the gap between current supply- and demand-side water requirement based on food balance matrix and trade balance matrix, focusing on green and blue water requirement.
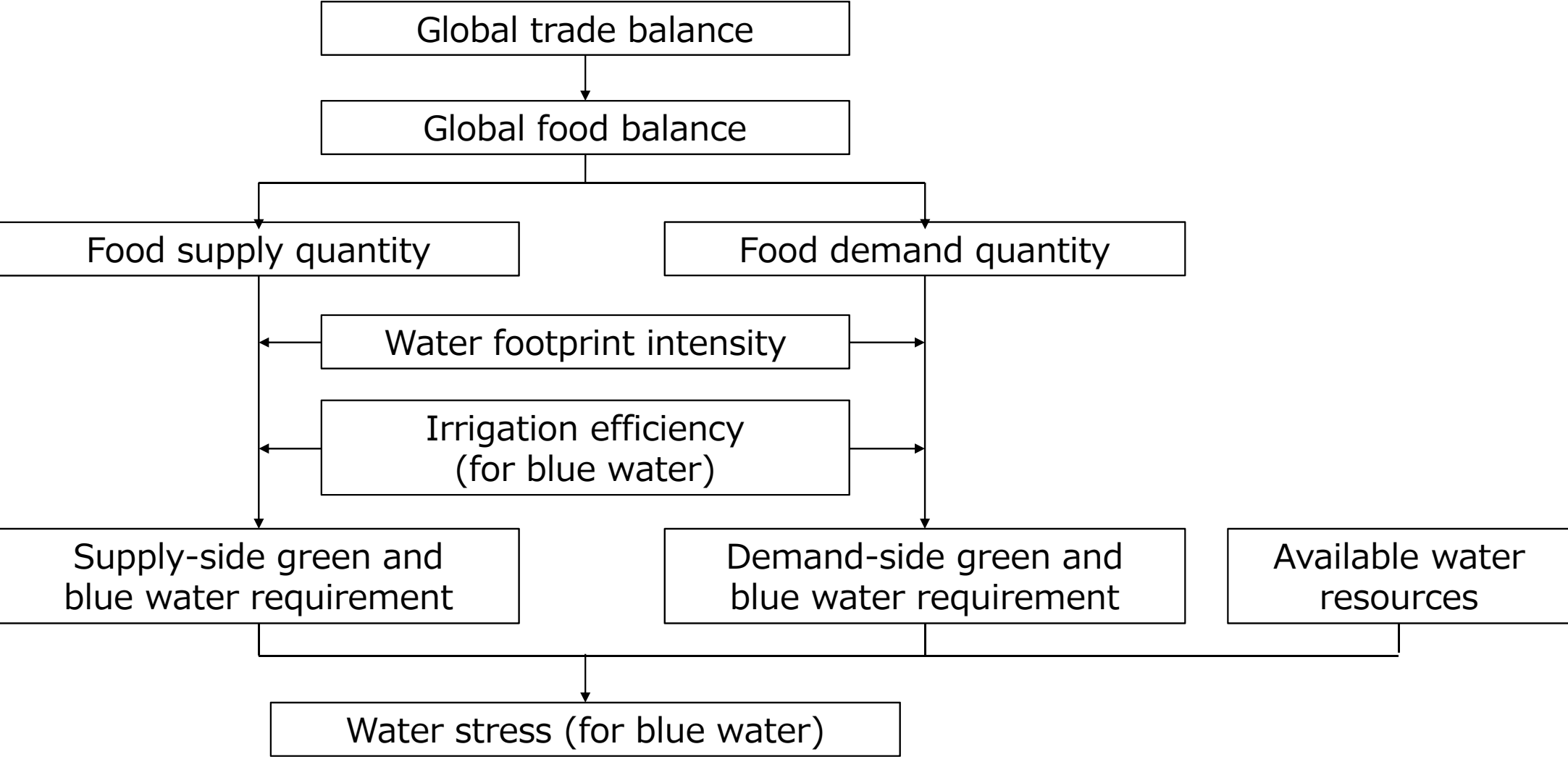
Evaluation Target and Data

- Evaluation Target

Evaluation Target	Detail
Reference year	In 2010
Country	216 countries
Item	78 items
Water consumption pattern	Green and blue water

- Main Data

Parameter	Database	Organization
Import breakdown of trade balance	FAOSTAT [3], Detailed trade balance	FAO
Various breakdown of food balance	FAOSTAT [3], Commodity Balances	FAO
Water footprint intensity	WFN Research Report Series [4]	WFN
Total Renewable water resources	AQUASTAT [5], Water resources	FAO
Water withdrawal by sector	AQUASTAT [5], Water use	FAO

Calculation Flow

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                    ┌─────────────────────────┐
                    │   Global trade balance  │
                    └─────────────────────────┘
                                 │
                                 ▼
                    ┌─────────────────────────┐
                    │    Global food balance   │
                    └─────────────────────────┘
```

Food supply quantity		Food demand quantity

	Water footprint intensity	

	Irrigation efficiency (for blue water)	

Supply-side green and blue water requirement	Demand-side green and blue water requirement	Available water resources

Water stress (for blue water)

Trade and Food Balance

Trade balance matrix

Item j	Importer			
	i_1	$\cdots$	i_r	Total
Exporter k_1	x_{11}	$\cdots$	x_{1r}	$\sum_r x_{1r}$
:	:	:	:	:
k_p	x_{p1}	$\cdots$	x_{pr}	$\sum_p x_{pr}$
Total	$\sum_p x_{p1}$	$\cdots$	$\sum_p x_{pr}$	$\sum_p \sum_r x_{pr}$

Row Sum = Column Sum

→ **by RAS Method**

Food balance matrix
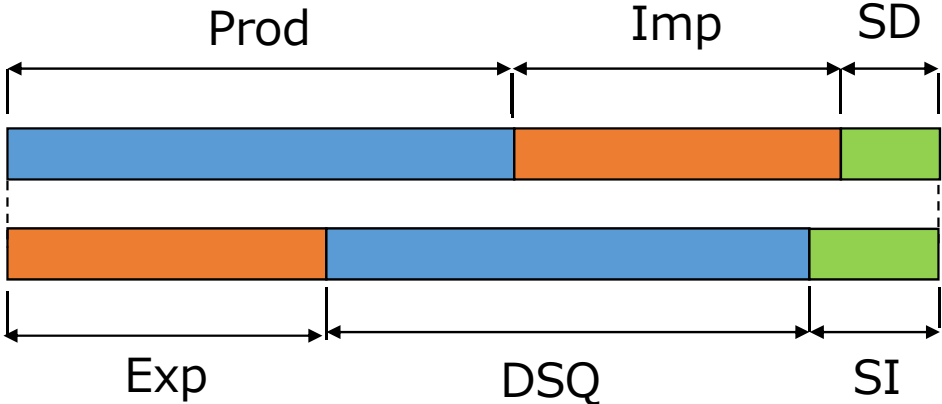
$SQ = Prod + Imp + SD$

$DQ = Exp + DSQ + SI$

SQ: Supply quantity [ton] DQ: Demand quantity [ton]

$Prod$: Production [ton] DSQ: Domestic supply quantity [ton]

Imp: Import quantity [ton] Exp: Export quantity [ton]

SD: Stock decrease [ton] SI: Stock increase [ton]

Water Footprint Calculation

● Trade model: Assumption of food trade between two countries.

→ Imported or exported items are all produced in their producing countries.

Trade partner of A for j	$Imp_{A,j,B}$	**Reporter**	$Imp_{A,j,C}$	**Trade partner of A for j**
Country B	⟵	Country A	⟵	Country C

$$Exp_{A,j,B} = Imp_{B,j,A}$$ $$Exp_{A,j,C} = Imp_{C,j,A}$$

● System boundary: Only direct consumption of growth stage is including.

Upstream ⟵   ⟶ **Downstream**

Non-livestock

Fertilizers

Agricultural implements

Crop growth → Breeding → Processing → Retailing → Final consumption

Livestock

Growth stage
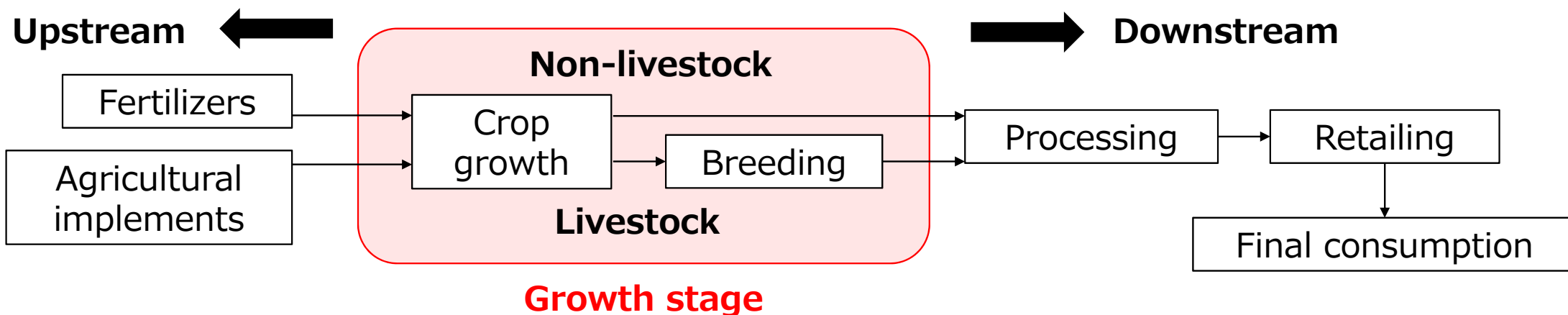
Water Stress Index

Real water stress index (RWSI)

$$RWSI_i = \sum_j \left\{ (WR_{Prod})_{Blue,i,j} + (WR_{SD})_{Blue,i,j} \right\} / AWR_i$$

$$AWR_i = TRWR_i \times \frac{AWW_i}{TWW_i}$$

Substantial water stress index (SWSI)

$$SWSI_i = \sum_j \left\{ (WR_{SQ})_{Blue,i,j} - (WR_{EQ})_{Blue,i,j} \right\} / AWR_i$$

● Criteria of Water Stress [6]:

WSI Ranges	Degrees of Water Stress
$WSI < 0.1$	No water stress
$0.1 \leq WSI < 0.2$	Low water stress
$0.2 \leq WSI < 0.4$	Moderate water stress
$0.4 \leq WSI < 0.8$	High water stress
$0.8 \leq WSI$	Very high water stress

WR: Water requirement [km³]

AWR: Available water resources [km³]

$TRWR$: Total renewable water resources [km³/yr]

AWW: Agricultural water withdrawal [km³/yr]

TWW: Total water withdrawal [km³/yr]
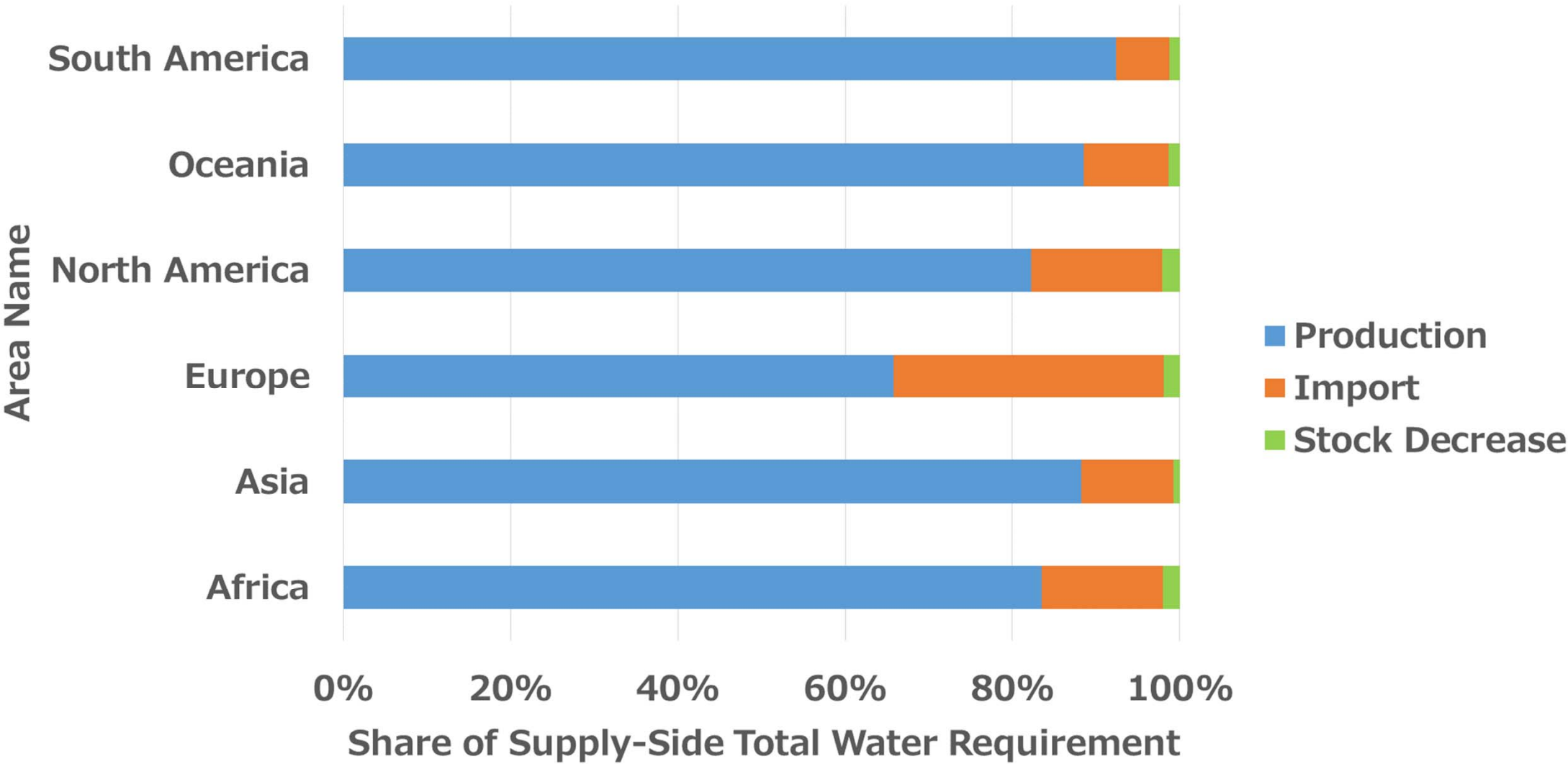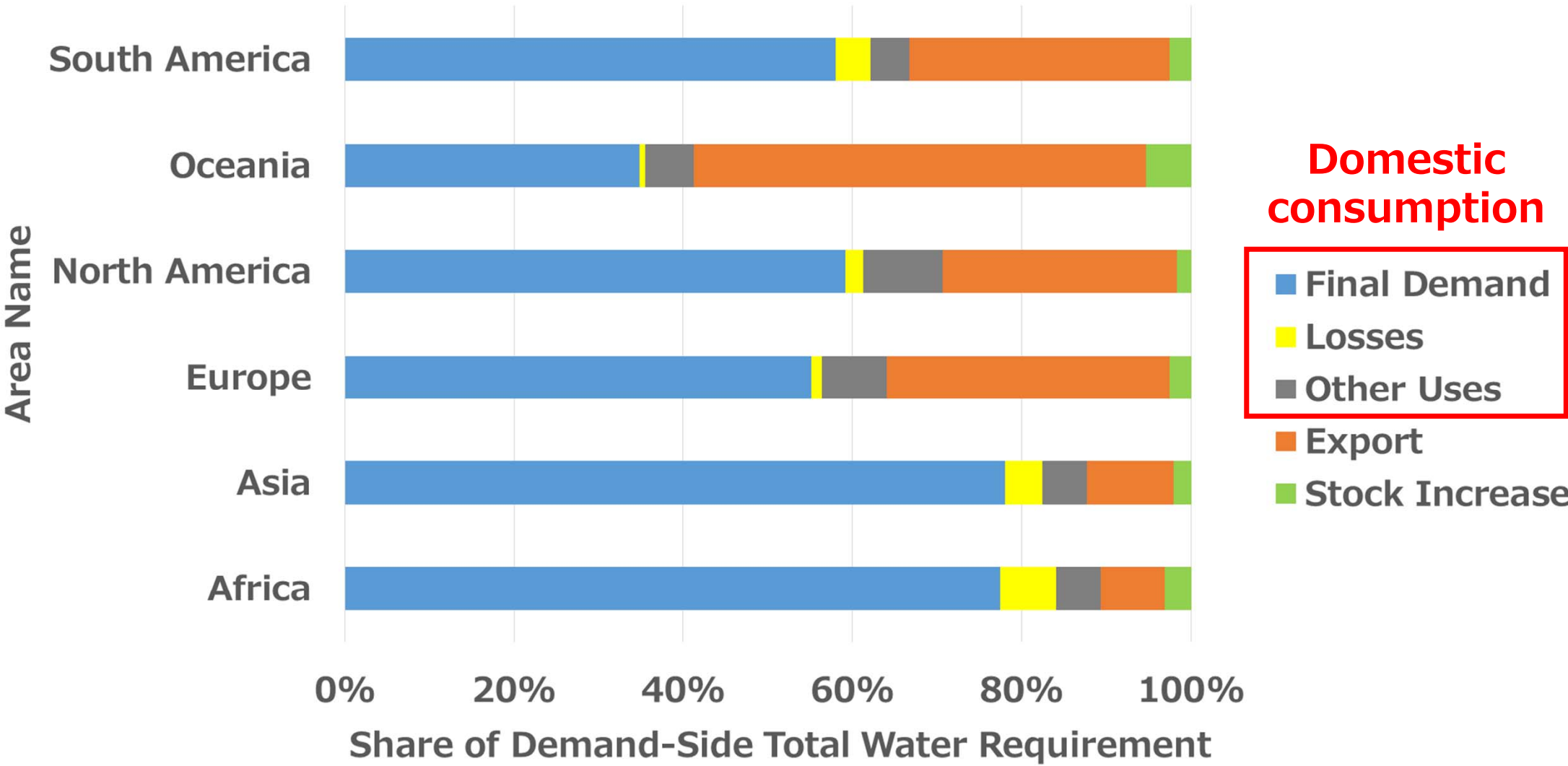
Green Water Requirement
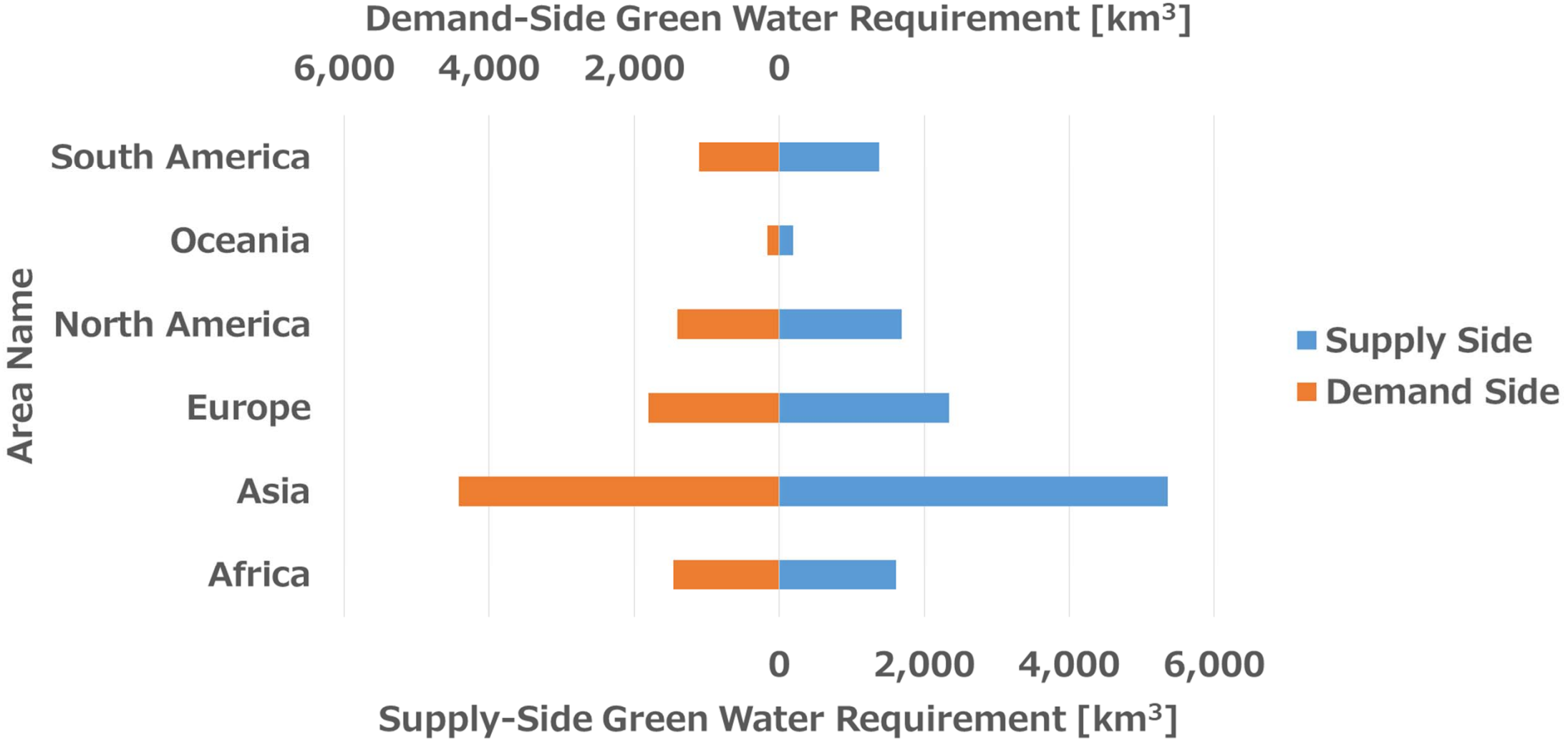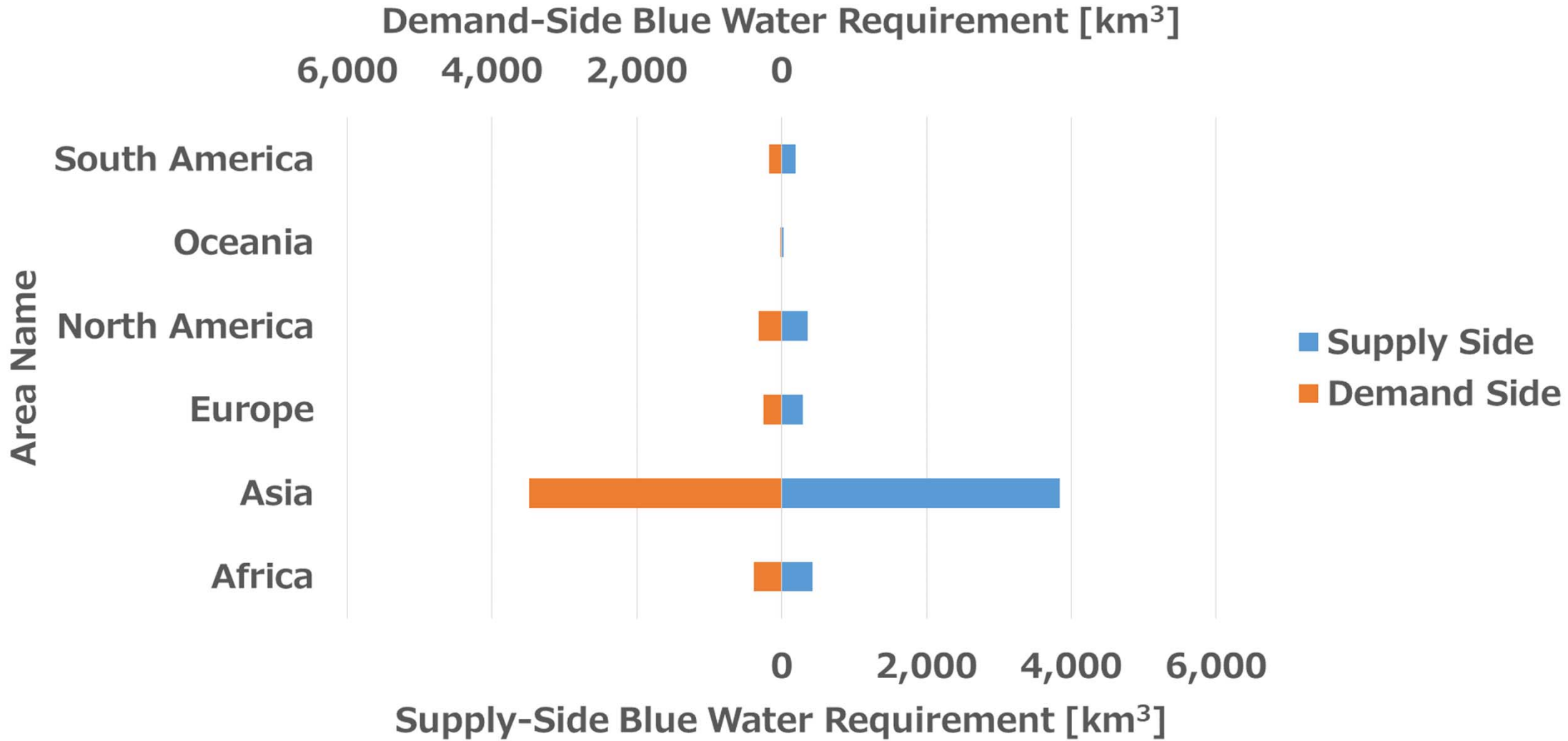
Blue Water Requirement

Share of Total Water Requirement

Share of Total Water Requirement

Real Water Stress

Very High Water Stress
High Water Stress
Moderate Water Stress
Low Water Stress
No Water Stress
Excluded Countries

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Substantial Water Stress

Very High Water Stress

High Water Stress

Moderate Water Stress

Low Water Stress

No Water Stress
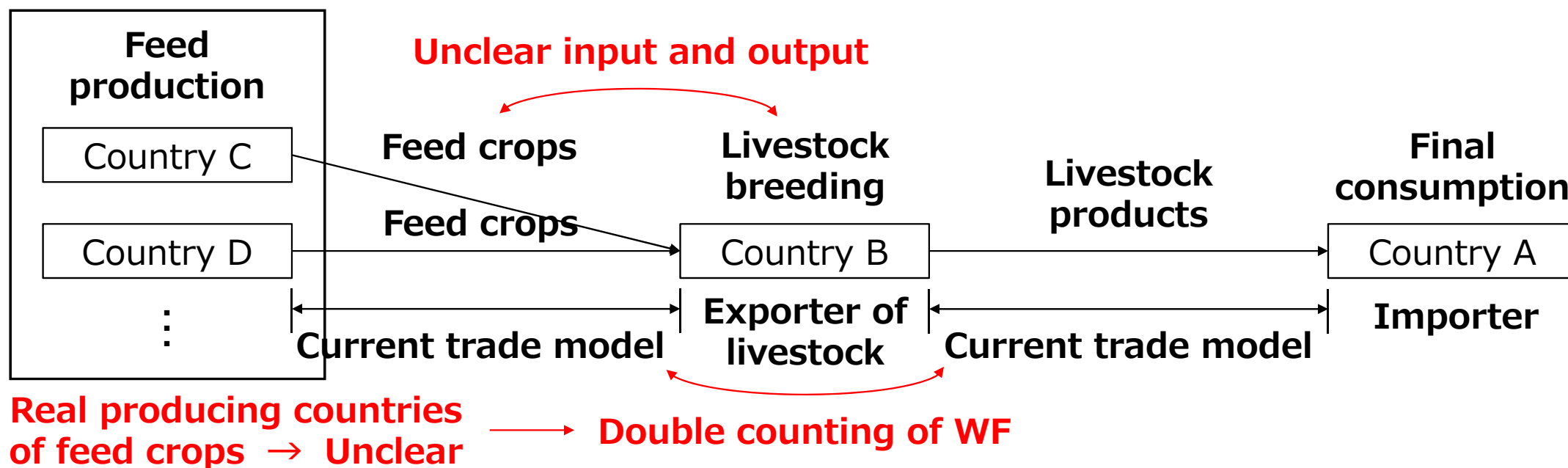
Excluded Countries

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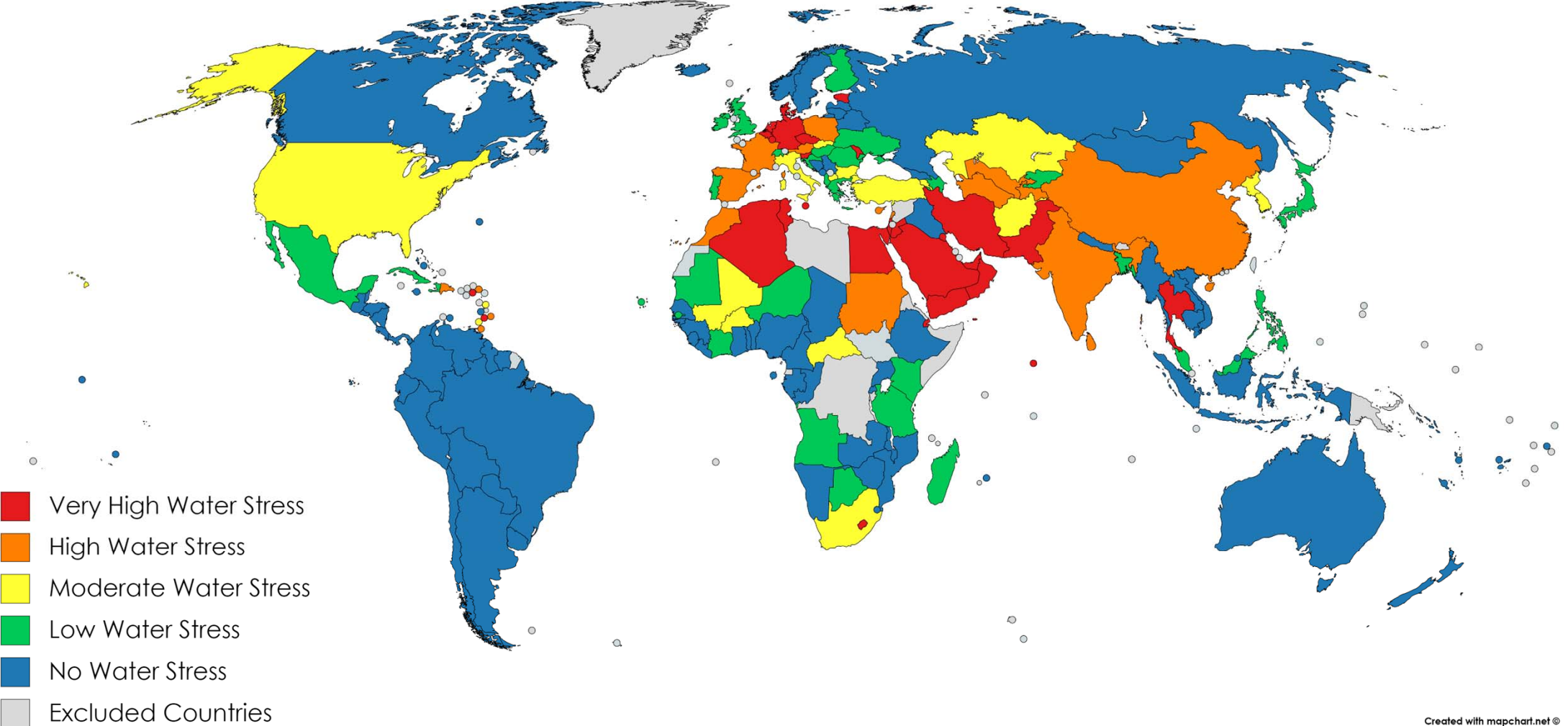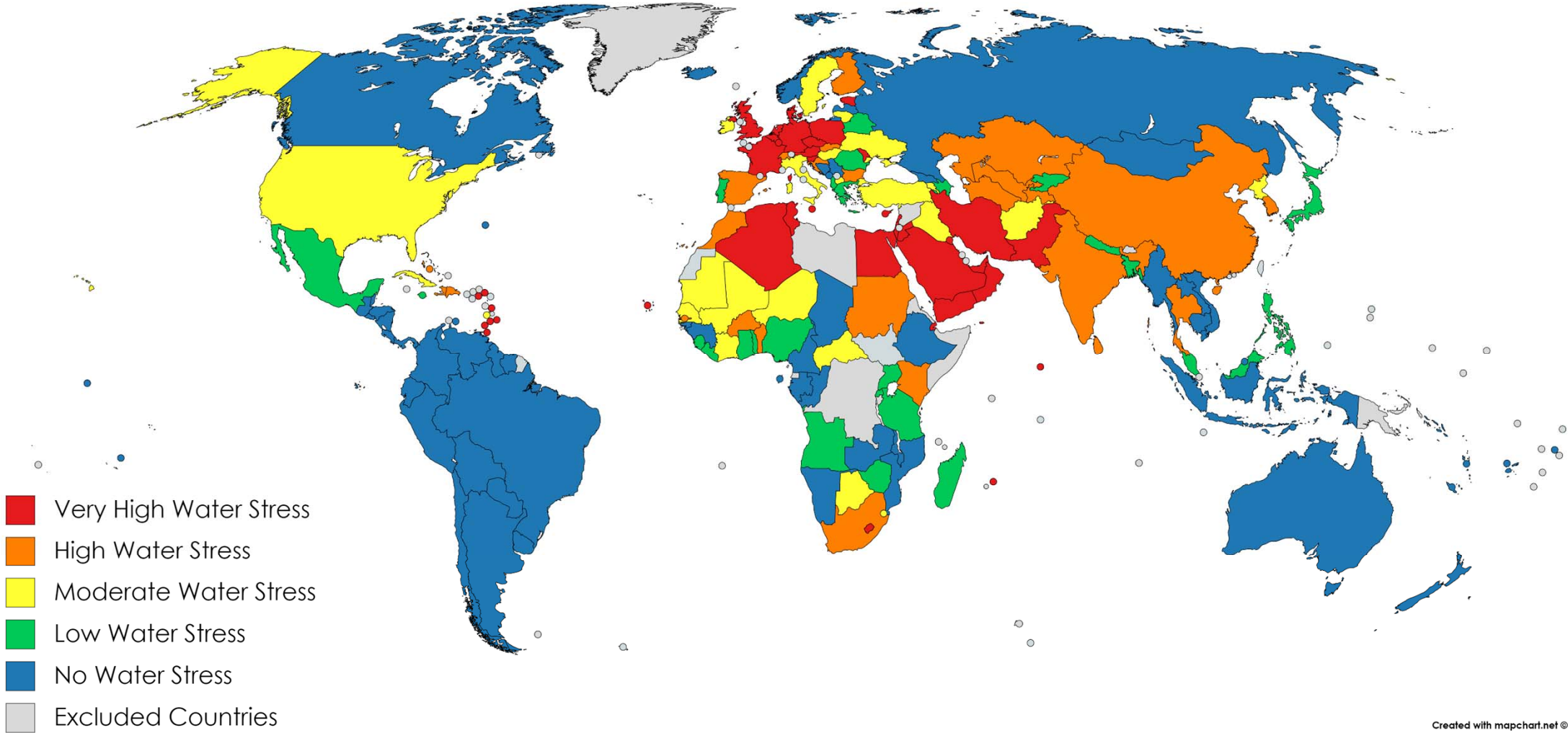
Conclusion

- Green water requirement is higher than blue water requirement (green: 70%, blue: 30% on global average). Asia is the largest water use region (green: 43%, blue: 75% of world).

- In Asia, Oceania, North and South America, production should be larger than domestic consumption. On the other hand, in Africa, domestic consumption is higher.

- In Oceania, North and South America, export is larger than import. On the other hand, in Africa, import is higher.

- For water stress, real water stress is smaller than or almost the same as substantial water stress.

Future Plans

- Detail analysis of water requirement associated with items or trade partners.
- Verifying the simulation values by comparing them with literature values.
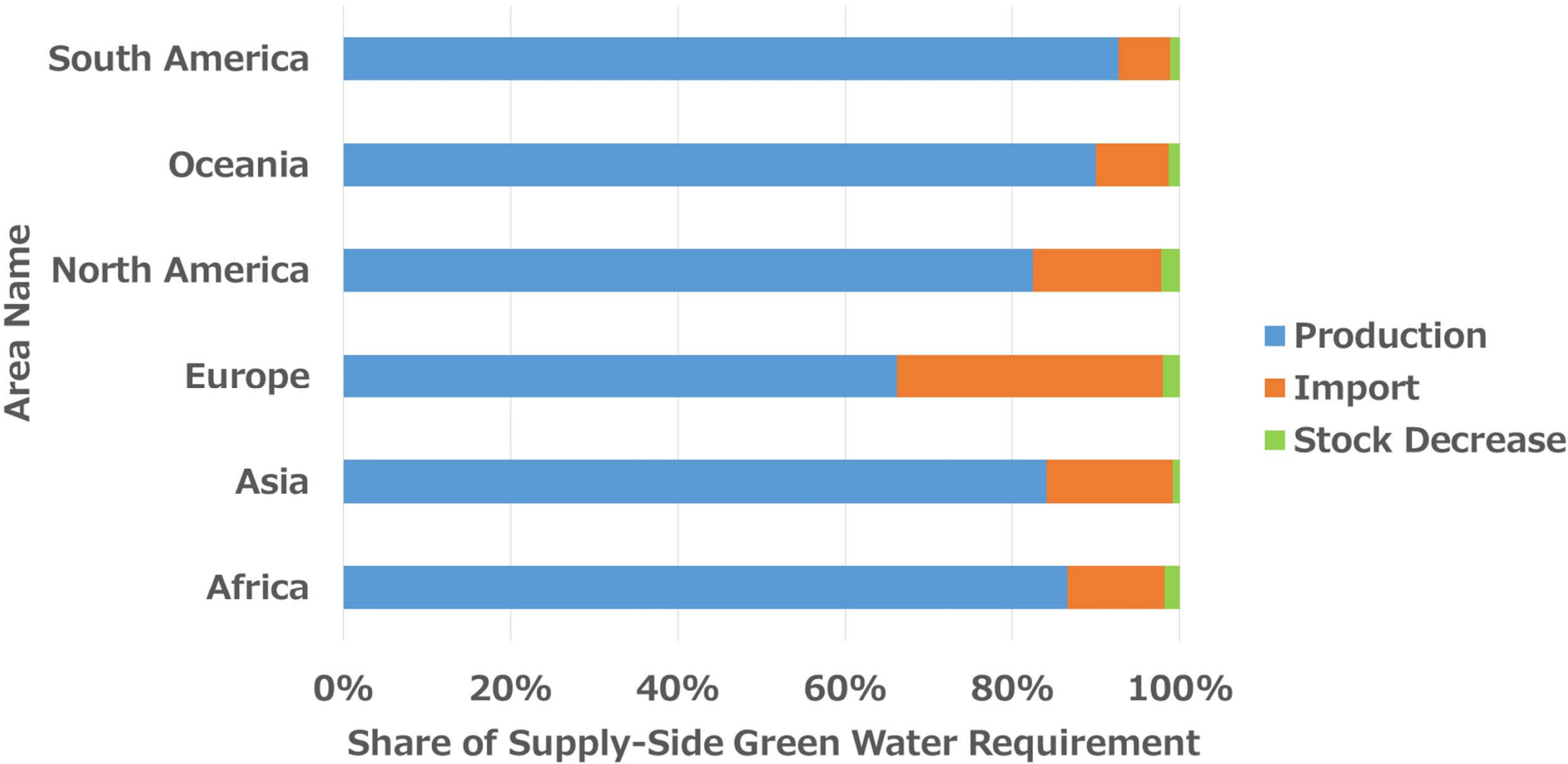- Specifying real producing countries of each intermediate items.

Unclear input and output

Feed production

| Country C |
| Country D |
:
:

Feed crops

Feed crops

Livestock breeding

| Country B |

Exporter of livestock

Livestock products

Final consumption

| Country A |

Importer

Current trade model

Current trade model

Real producing countries of feed crops → Unclear ⟶ **Double counting of WF**

Thank you for your kind attention.

References
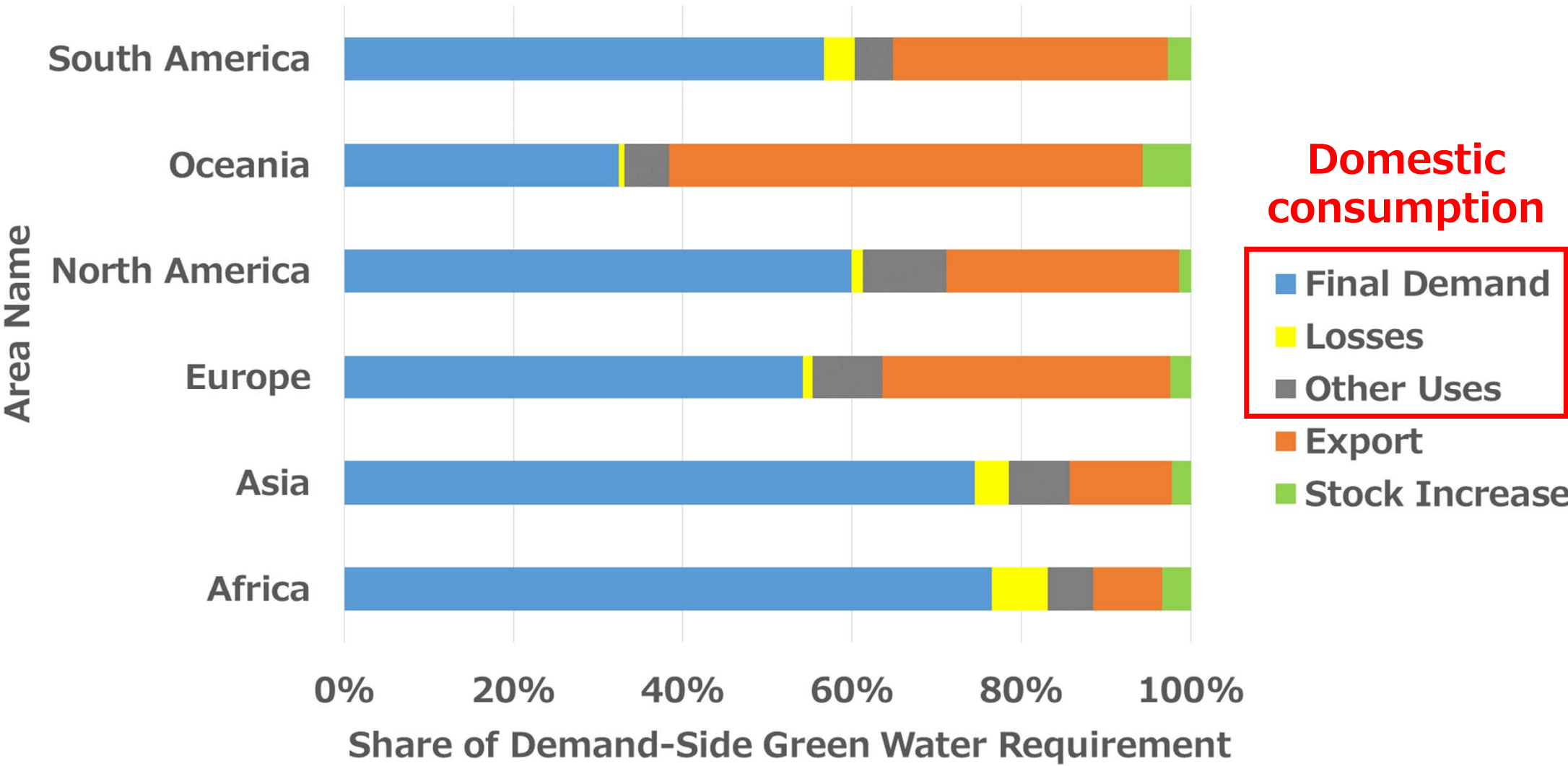
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2) Yamaguchi Y., Tamura K., Yoshikawa N., Amano K., and Hashimoto S. (2017): Journal of Life Cycle Assessment, Japan, 14(1), 21-35.

3) FAO: FAOSTAT, FAOホームページ, <http://www.fao.org/faostat/en/#data>

4) Mekonnen M. M. and Hoekstra Y. A. (2011): National water footprint accounts: The green, blue and grey water footprint of production and consumption – Volume 2: Appendices, Value of Water Research Report Series, No.50, UNESCO-IHE, Delft, NLD, 1-94

5) FAO, AQUASTAT, FAOホームページ, <http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en>,

6) Smakhtin V., Revenga C. and Doll P. (2004): Taking into account environmental water requirements in global-scale water resources assessments, Comprehensive Assessment Research Report 2, Comprehensive Assessment of Water Management in Agriculture, IWMI, Colombo, Sri Lanka, 1-32.

Share of Green Water Requirement

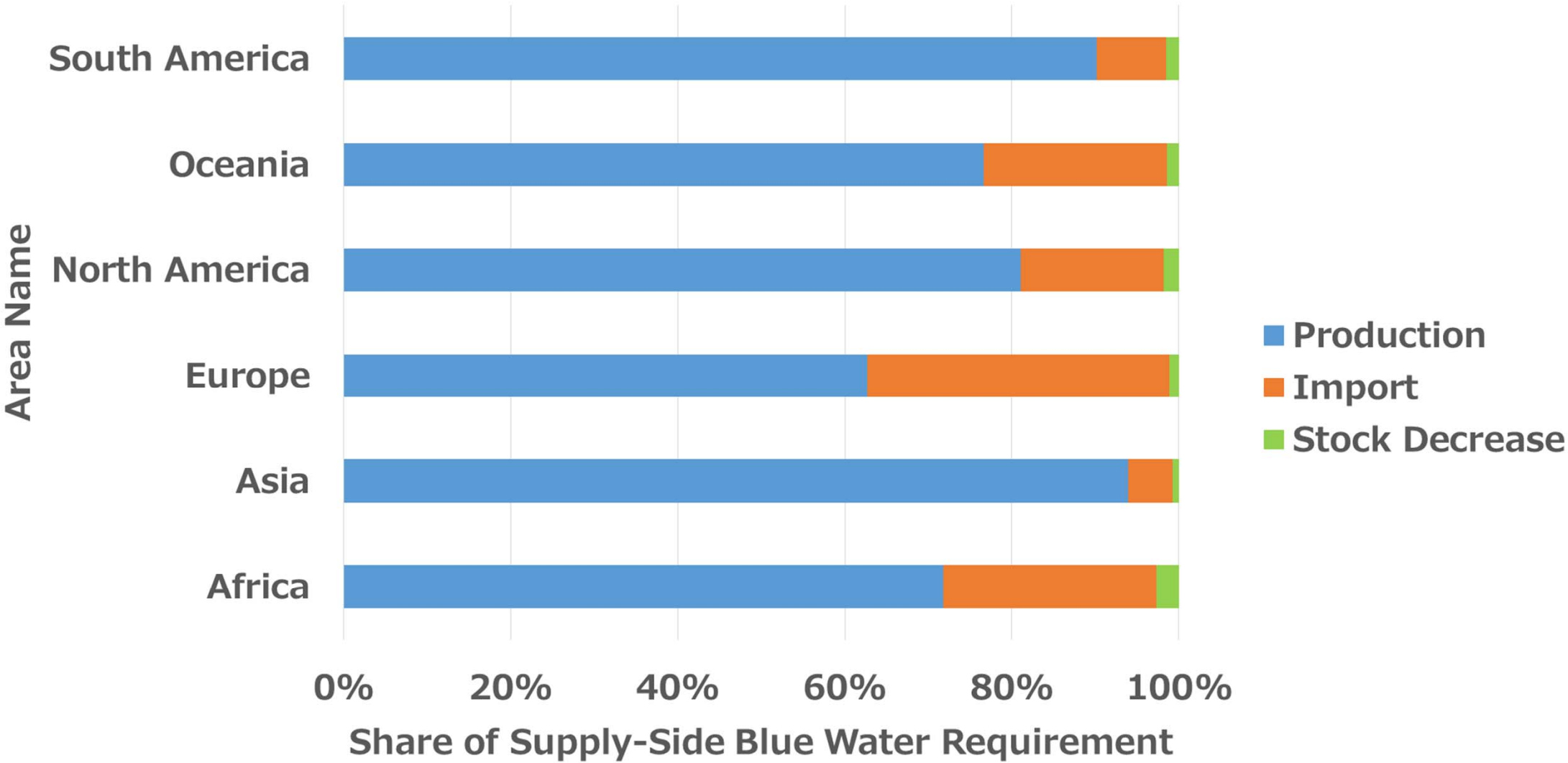# Share of Green Water Requirement

Share of Blue Water Requirement

Share of Blue Water Requirement