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NEXUS Gains

Governing irrigation efficiency (IE) to solve the four-body problem of lowering water consumption whilst not cutting food production, increasing CO_2 emissions and reducing water equity

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Governing IE to solve a four-body problem

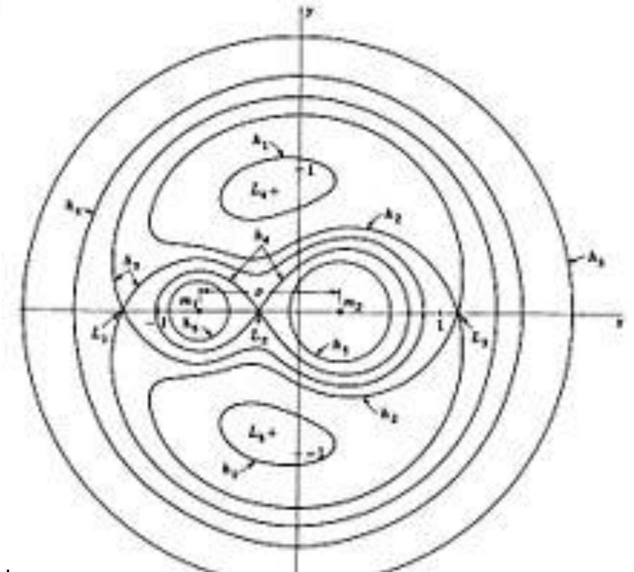

Image: https://en.wikipedia.org/wiki/N-body_problem

In celestial mechanics, a three or four body problem presents fiendishly difficult mathematics – meaning the gravitational motion of three or four planets / moons / spacecraft cannot be easily resolved.

Likewise, applying irrigation efficiency to resolve four goals

1) reduce aggregate water depletion; 2) not cut crop production (esp. staples/cereals); 3) not increase energy use (esp. CO_2 emissions); 4) enhance water equity between farmers & between sectors

is mathematically complicated due to high number of system factors which are often uncontrolled/not managed

If we apply IE in isolation we may raise water consumption (which can add crop biomass but change crops), increase energy use & sharpen inequality

Instead, to achieve nexus / SDG goals, we need to **govern IE** & interconnected system factors & drivers that affect multi-scale irrigated systems & catchments

Irrigation efficiency; a beguiling ratio

Mathematically, IE is the ratio of crop beneficial consumption to irrigation withdrawals (classical IE) or ratio of BC to irrigation depletion (effective IE)

IE is at the centre of contradictions contributing to the four-body problem of something difficult to resolve and govern. E.g. an increased IE occurs if we

- … increase the proportion of BC relative to withdrawals
- … decrease withdrawals relative to BC
- … convert non-recovered/non-ben C to greater BC and/or lower withdrawals

IE is at the centre of complicated distinctions between **real water savings** (a drop in aggregate depletion at the catchment scale) and **paper water savings** (lower field level applications and/or a cut in water withdrawals)

IE is indirectly mediated via changes to irrigation technology & practices

IE & agro-hydrology: very difficult to measure across field, system, basin scales

Raising IE redistributes water in a paracommons; a commons of salvaged water – who gets the material gains of an efficiency gain?

IE is an interconnector between water actors/paracommoners

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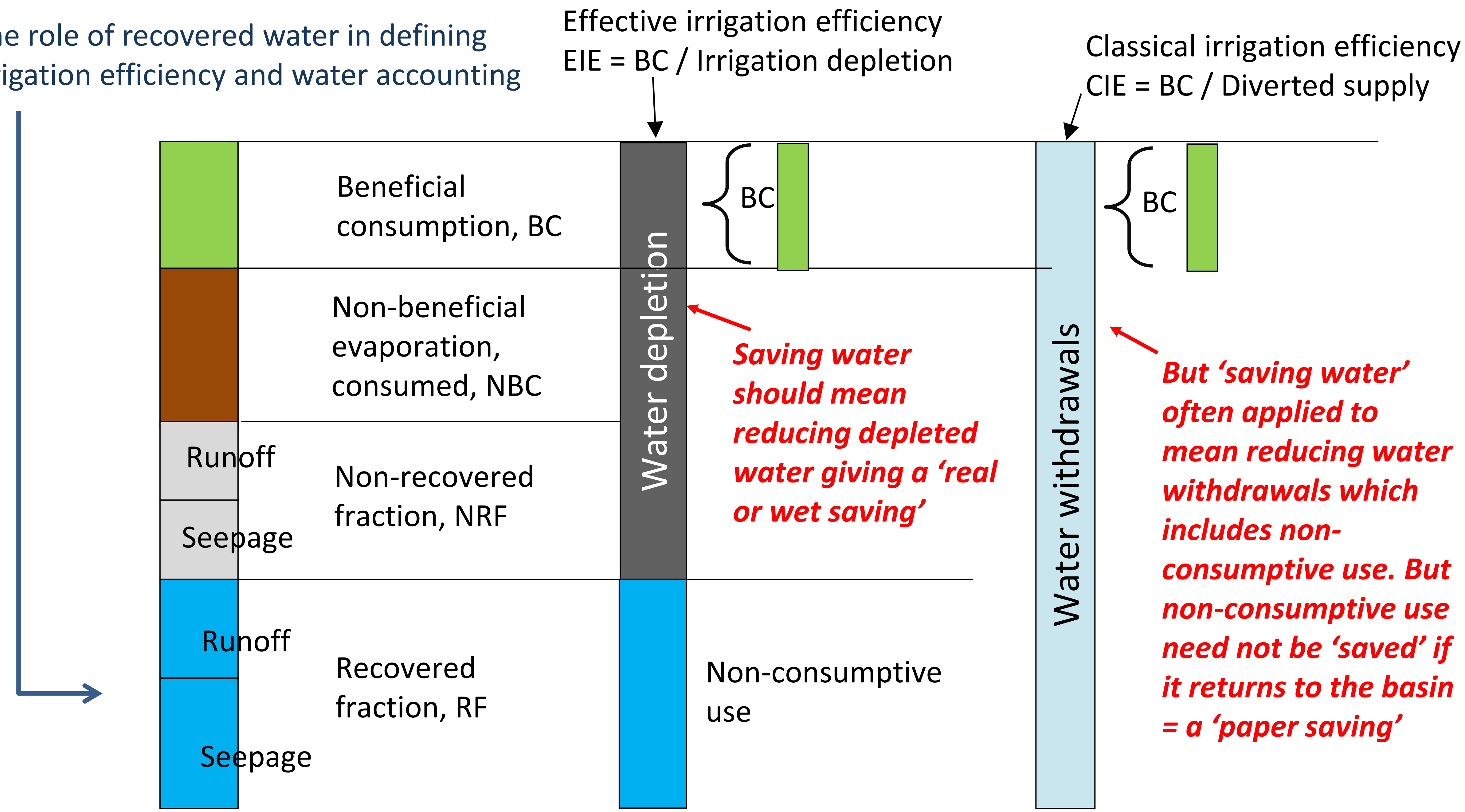
The role of recovered water in defining irrigation efficiency and water accounting



Not governing IE gives unforeseen or undesirable nexus orbits as a four-body problem

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Powerful irrigation actors in basins gain more water

Raising irrigation efficiency in isolation

Move to commercial horticultural row crops; risking broadacre staples & cereals

Greater energy consumption

More water consumption

Not governing IE gives unforeseen or undesirable nexus orbits as a four-body problem

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Improve equity between water sectors

Raising irrigation efficiency in isolation

Sustain food production and security

Increase energy consumption

Reduce water consumption

Difficult to govern due to political economy of IE & irrigation/water infrastructure. Costs & risks

Surface/gravity irrigation

Drip irrigation

Old waste dripper lines in sugarcane; & drip for table grapes Jordan

More/changes to, irrigation infrastructure (irrig area, intakes, canals, pumps, pipes, storage, boreholes, infield tech & soil mgt, energy) = harnesses, stores, withdraws & distributes more water = drives up consumption

Subsidised/political economy of rural/farmer electorate in ‘modern agric’ narratives

- Energy emissions (if fossil fuel): 0.0 kg CO_2/m^3 (gravity) to 0.2 kg CO_2/m^3 (drip)
- Drip suits horticultural row crops (not cereals/staples → food security concerns)
- Drip suits water-rich commercial growers, not smallholder/public irrig. systems
- Brings social costs to farmer groups operating/maintaining pressurised systems

Sustaining (pareto-checked) crop production when cutting aggregate depletion

Thorny question at the centre of resolving the four-body problem of IE:
Can we reduce aggregate water depletion in irrigation for reallocation to other sectors/users without cutting crop production?

PhD research on rice irrigation in southern Tanzania by Machibya Magayane unpublished


Water-rich top-ender rice nurseries; 2540 mm for 2-4 t/ha


Water-short tail-ender nurseries; 930 mm for 2.7-4.5 t/ha

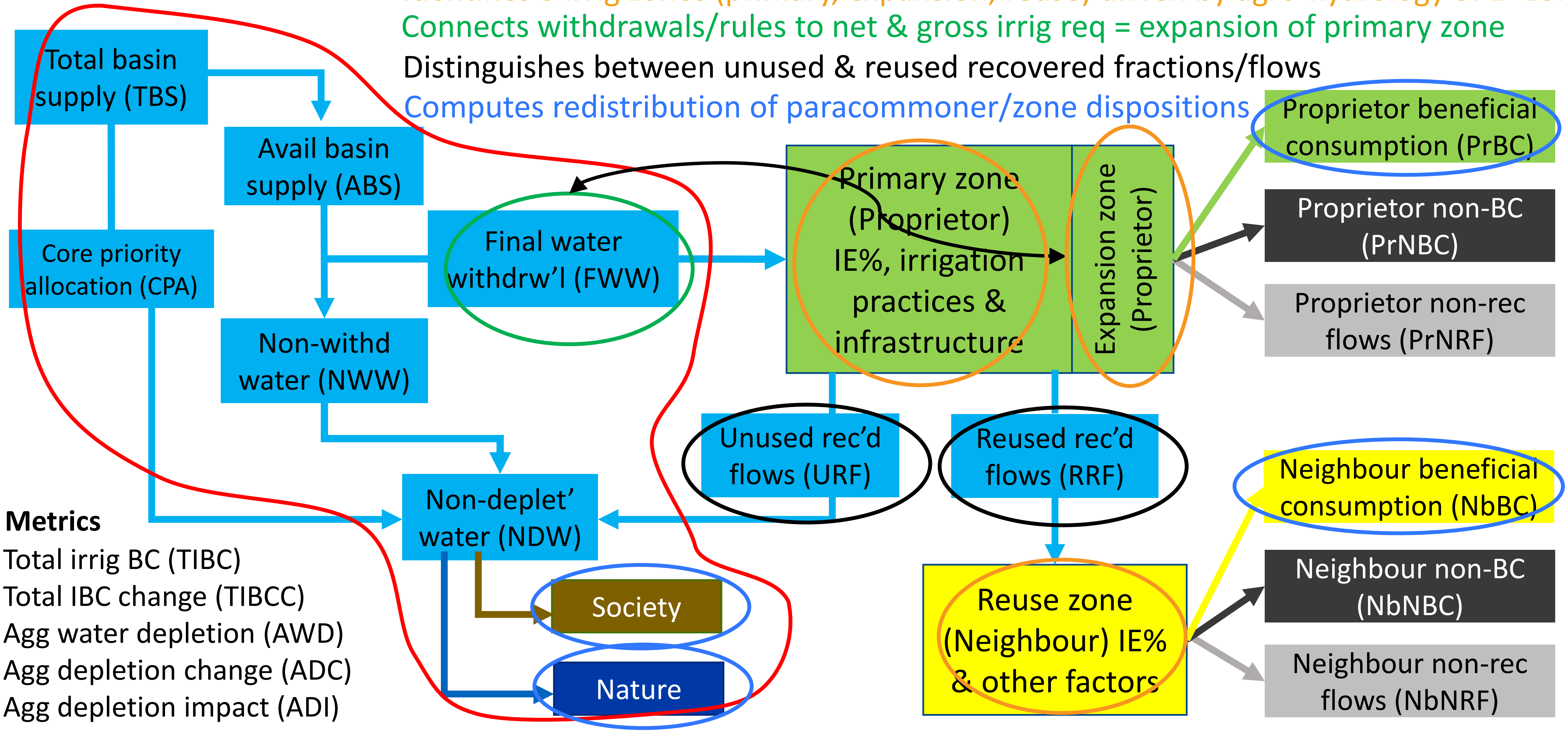
Higher IE raises crop productivity *if water to and within irrigation is controlled:*

- Puts greater % of withdrawn water to crop beneficial consumption and growth
- Improves water timing/scheduling between farmers, reduces the duration of crop stress
- Improves water uniformity within-field, and cuts non-recovered and non-beneficial consumption arising within water distribution, and within & at the edge of fields
- Enables agronomic practices such as deficit irrigation, fertiliser dosing, & mgt of soil salts
- Reduces nutrient leaching, potential soil erosion, costs of pumping / filtering water

A comprehensive accounting model of agro-hydrological change is central to governing & solving benefits of IE

Lankford 2023
Lankford & Scott 2023
Latest = my own website

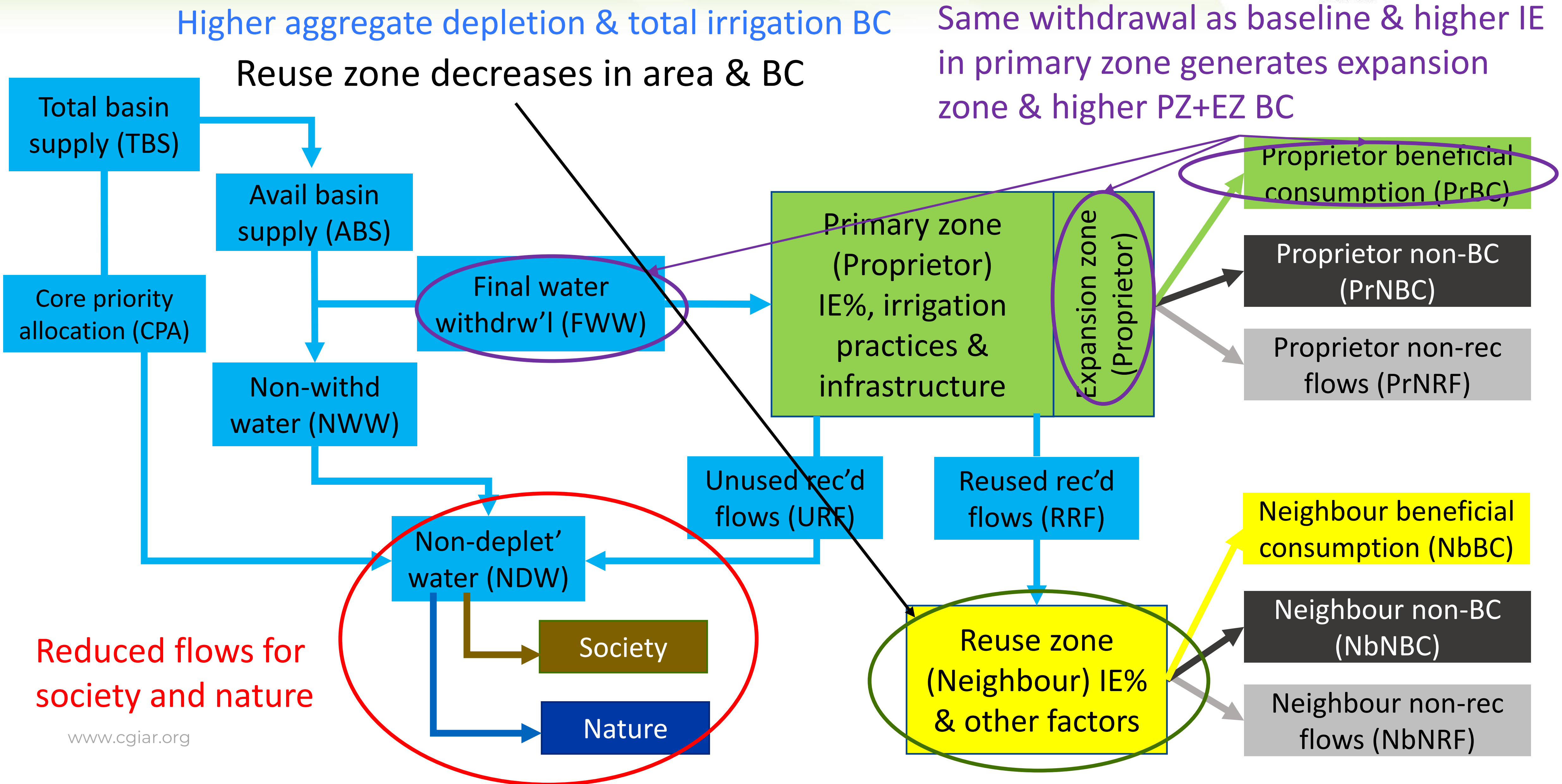
Accounts for catchment supplies & water allocations
Identifies 3 irrig zones (primary, expansion, reuse) driven by agro-hydrology of 1º zone
Connects withdrawals/rules to net & gross irrig req = expansion of primary zone
Distinguishes between unused & reused recovered fractions/flows
Computes redistribution of paracommoner/zone dispositions



Metrics
Total irrig BC (TIBC)
Total IBC change (TIBCC)
Agg water depletion (AWD)
Agg depletion change (ADC)
Agg depletion impact (ADI)

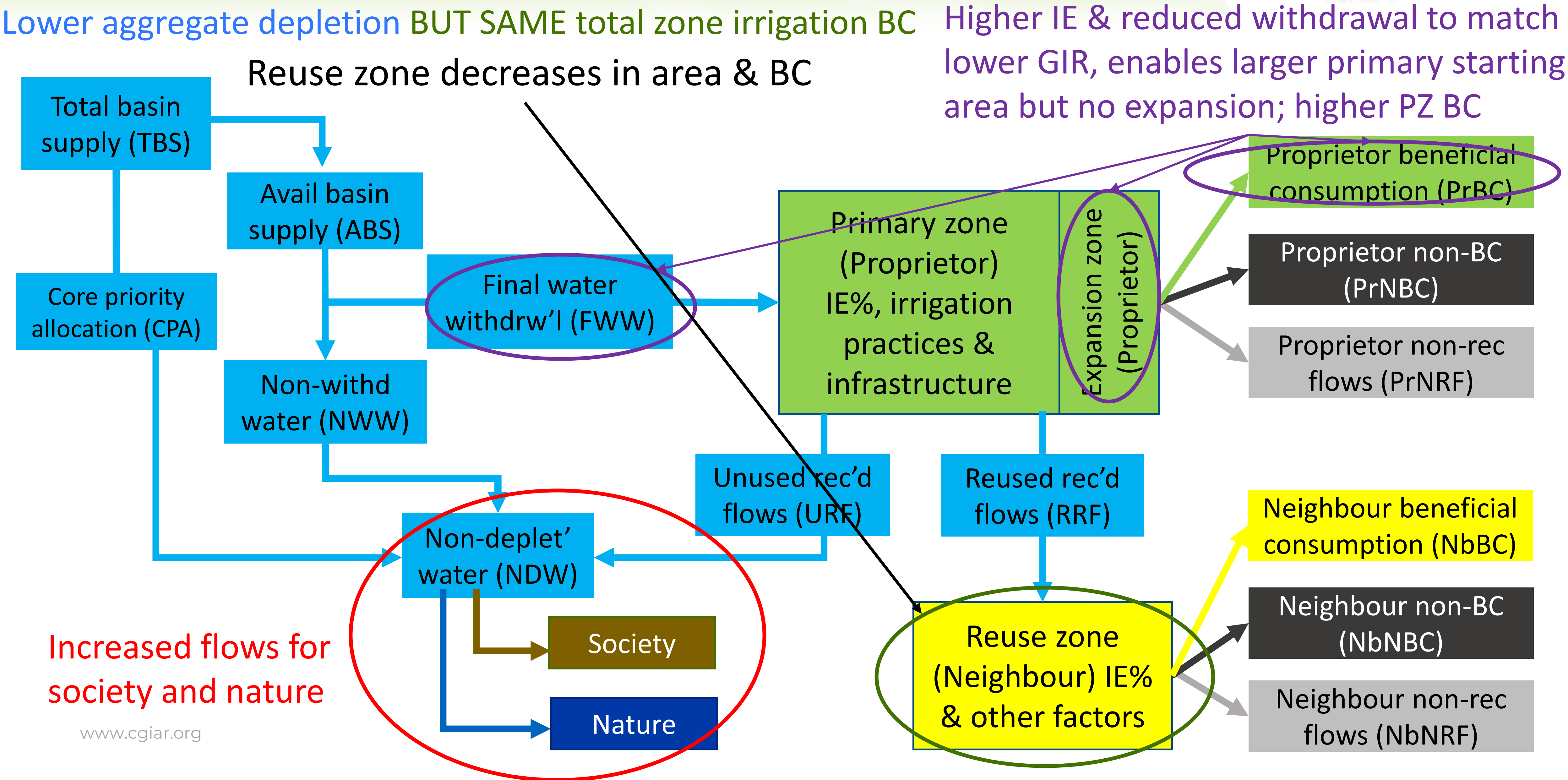
Inducing a paradoxical rebound from raising IE

See appendix slides



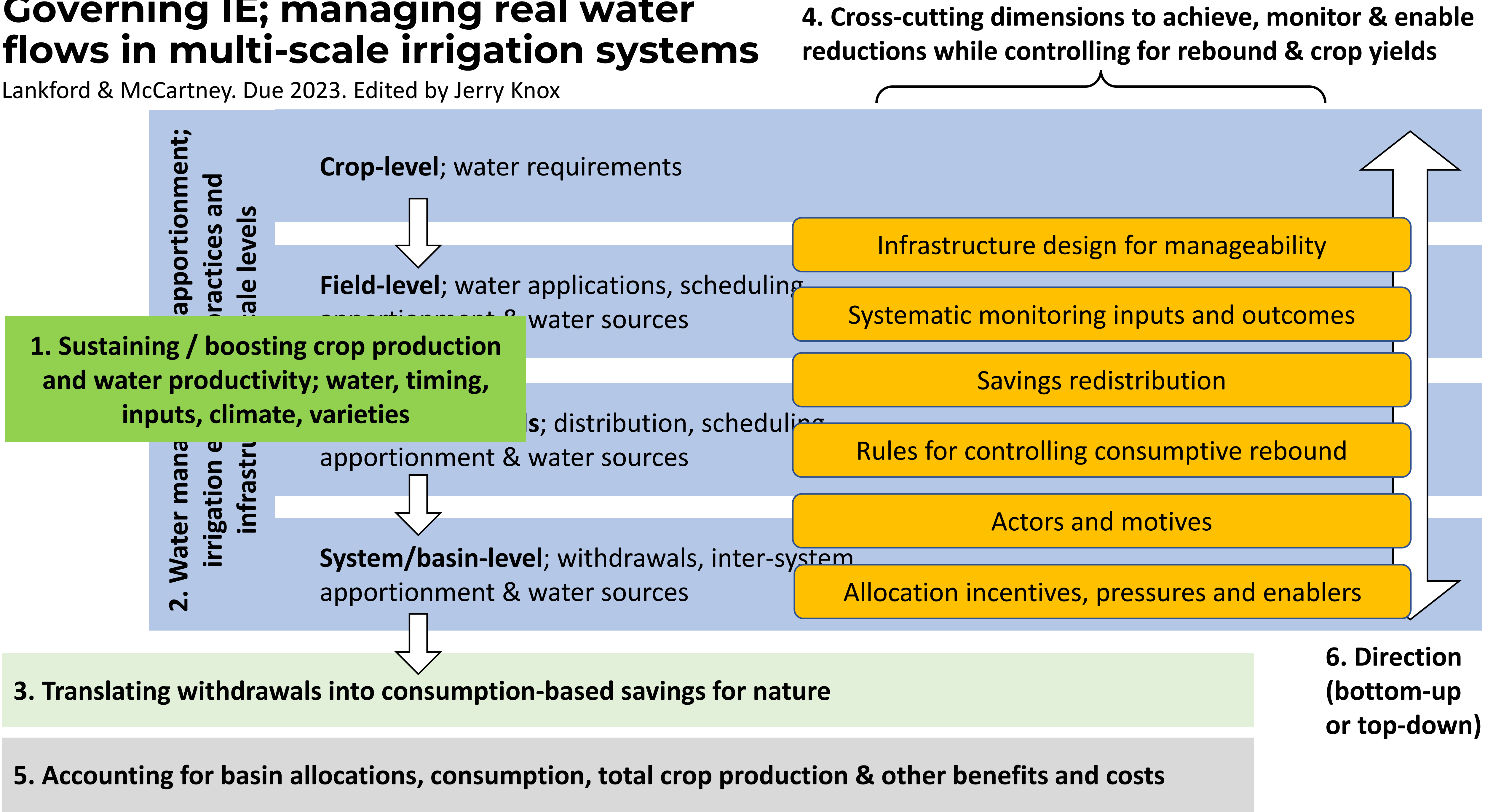
Achieving pareto-neutral real water savings

See appendix slides



Governing IE; managing real water flows in multi-scale irrigation systems

Lankford & McCartney. Due 2023. Edited by Jerry Knox



Conclusions

- Flourishing frugal irrigation benefits crop production, water reallocation, energy & emissions, and water livelihoods & equity
- To control the rebounds, gains & costs from raising irrigation efficiency requires us to govern IE & its associated factors. This is not an easy task.
- Water conservation; distributive interpretive act – confounding prefigurations
- Resolving the four-body problem of irrigation efficiency means we will need to manage better 1000s of hectares of gravity/surface irrigation globally
- Requires better/more empirical research of irrigation at different scales. Yet we have lost all Master’s degrees in irrigation
- With these lacks, are we putting our faith in models, & too few ‘single scale’ water mgt tools? (E.g. satellite images, soil sensors, & social qualitative data)
- Governing irrigation (& efficiency) needs a comprehensive approach across different scales, disciplines and voices, using variety of quantitative/digital/social tools; whilst bearing down on political economy of IE & water extraction.

False precision & assumptions with accounting if little field research

Democratic scenario-building & discussions (not only experts)

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Conclusions: sole focus vs governing irrigation efficiency

	Single focus on irrigation efficiency	Governing irrigation efficiency
Explanation	Solely increasing IE **OR** obscuring IE **OR** not recognising benefits of higher IE	Consider benefits of IE via a multi-scale/ -factor / -voice / -disciplinary framework
Scales (inc people, motives, drivers)	One scale (field or system) or two scales (field and catchment **OR** field and farm)	Across scales; field, farm, tertiary and secondary unit, system, catchment, global
Main technology	Focus on wholesale tech change (drip)	***Managing*** gravity, drip, sprinkler
Who gets the gain? (Paracommoner)	The farmer implementing change (proprietor/primary zone can expand)	Purposively reallocated; nexus gains (Proprietor, neighbour, nature, society)
Role of other controlling factors	Usually ignored or left uncontrolled	Irrigation area, withdrawals, timing, duration & use of other 'waters'
Interpretations to guide/caution	Mistaking paper savings **OR** only flagging real water savings & paradoxical outcomes	Connecting paper savings (= real water) to real savings in messy middle; all voices inc farmers
Accounting & tools	Simple accounting frameworks or too few tools for water management	Comprehensive digital tools & frameworks covering all scales and real water flows

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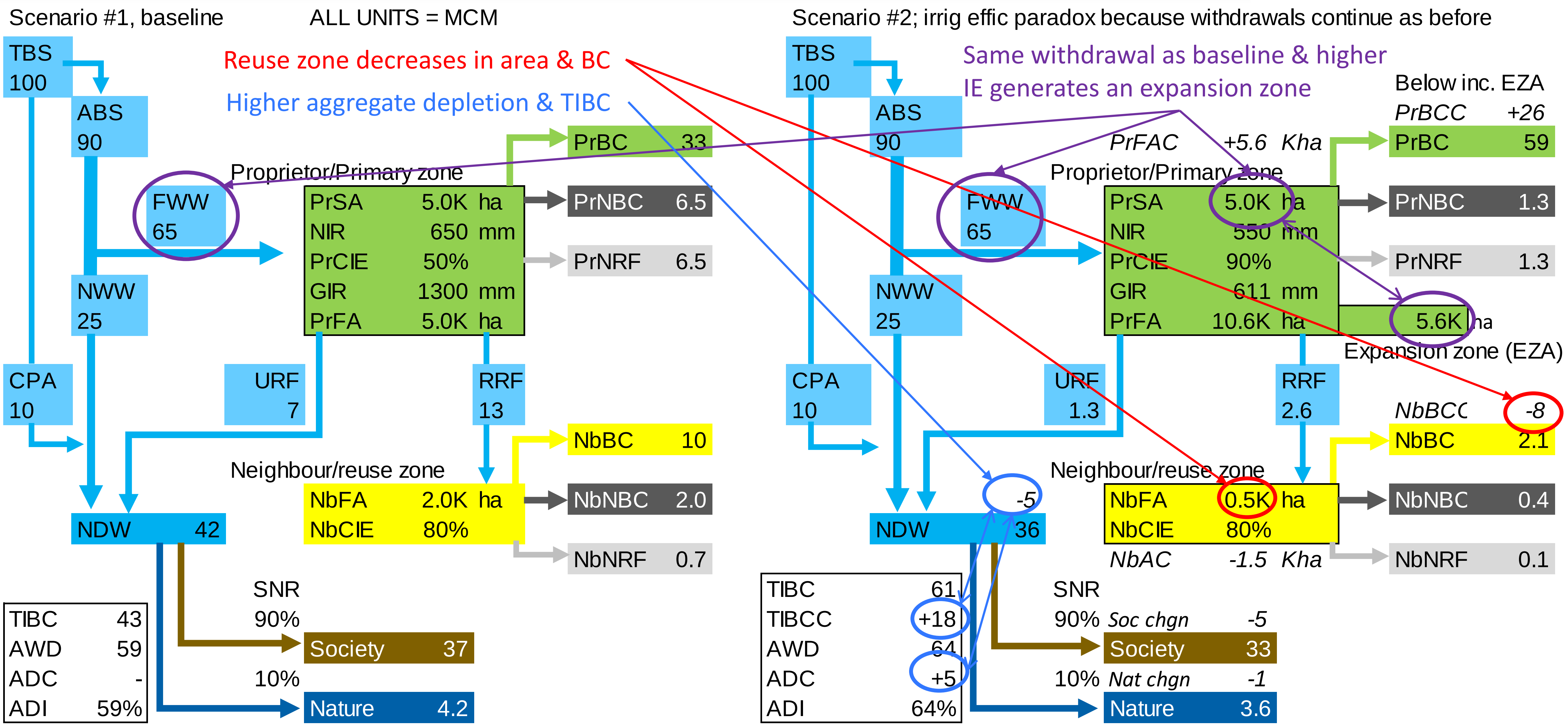
Not controlling variables in the paracommons; inducing an irrig. effic. rebound via expansion of the primary area but not from reduced reuse of water



Controlling withdrawals, IE and area in the paracommons for pareto neutral real water savings

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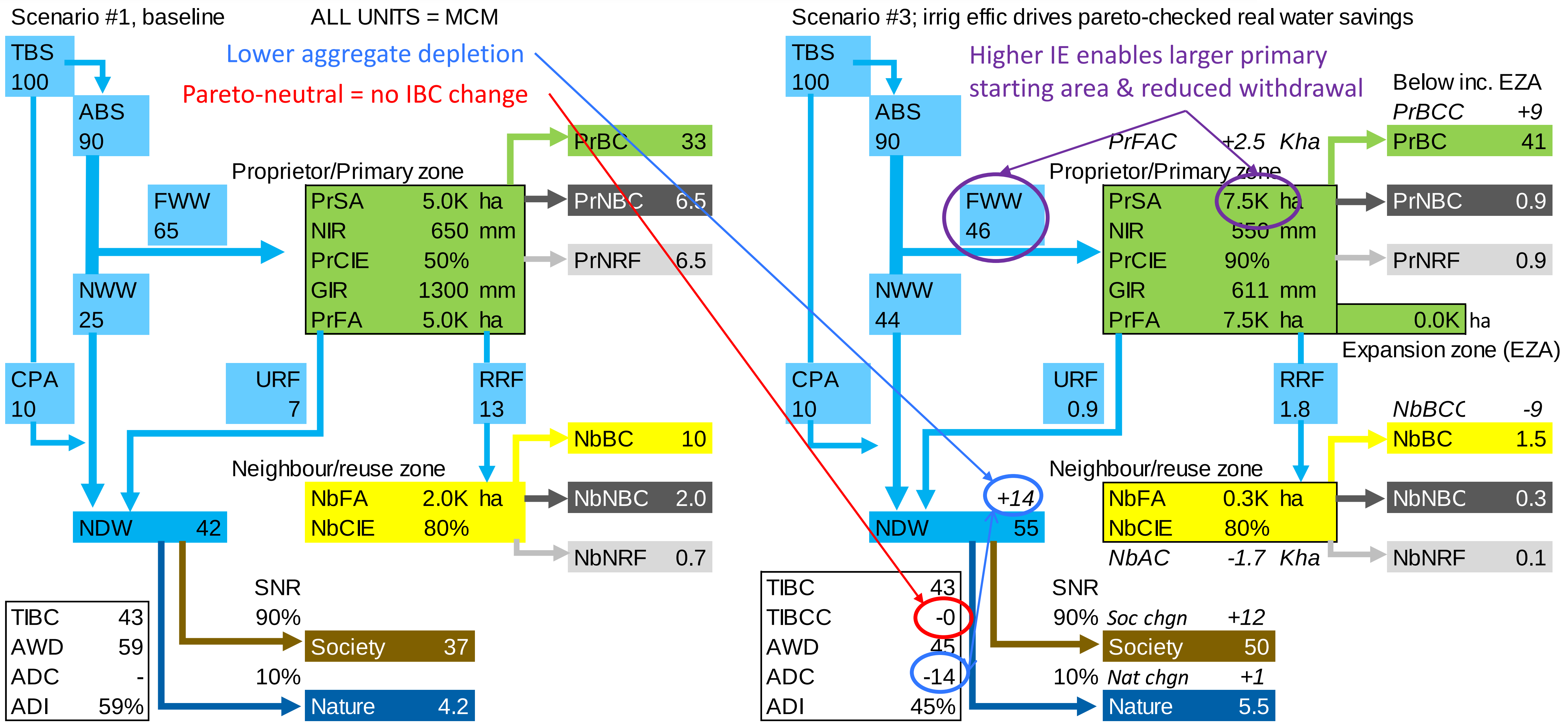

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