Reexamining the Social Context of Critical Natural Capital

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What is Critical Natural Capital (CNC)?

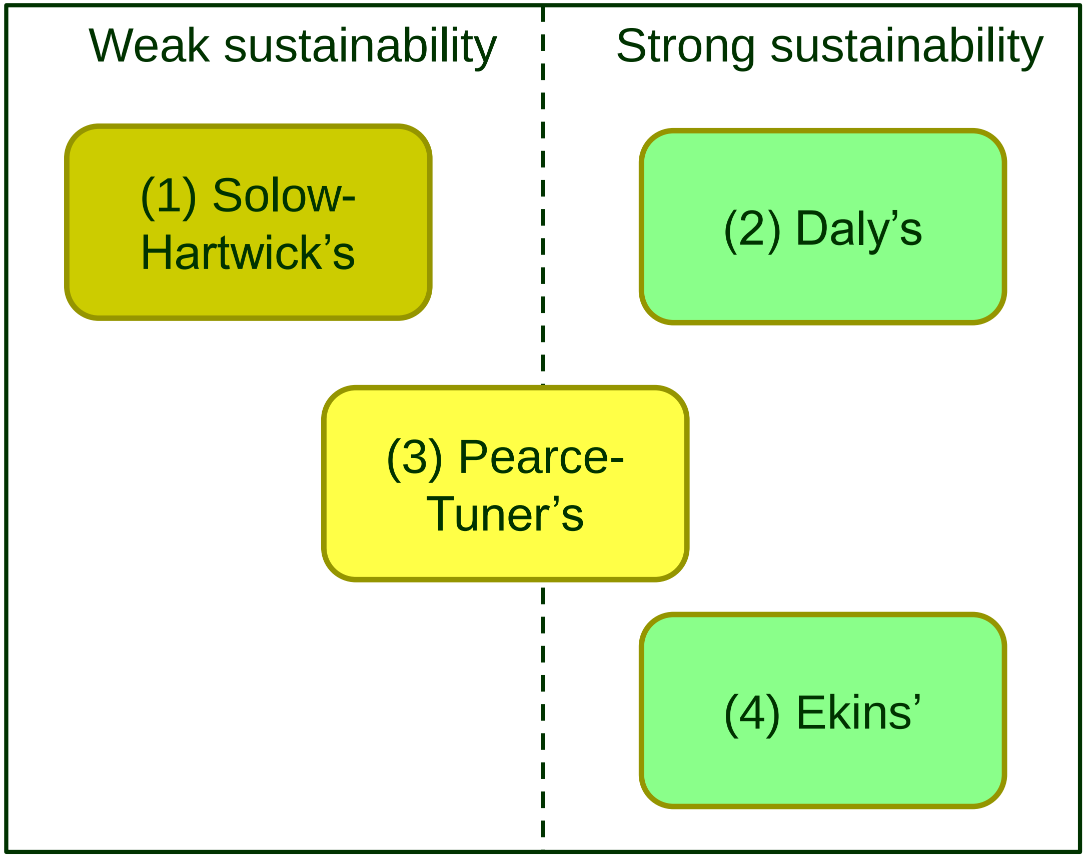
- Pearce et al. (1993) introduced CNC to capture the property of non-substitutability of natural capital.
  - "Ecological assets which are essential for human well-being and survival" (Pearce et al. 1993)
- Ekins et al. (2003) developed a framework for the identification of CNC based on physical measures.
- Recently, Pearson et al. (2012) offers the philosophical interpretation of CNC (with a emphasis on deontology). Also, Pelenc and Ballet (2015) link CNC with A. Sen's concept of capability.
- CNC has been discussed under the paradigm of SS, however, the conditions for identifying CNC are not fully examined so far.

Purpose of this paper

- Research question:
  - How can the existing sustainability theories provide the theoretical bases of CNC?
  - What is the conditions for identifying CNC?
- To clarify the conditions of CNC based on the existing sustainability theories.
- To examine the conceptual issues of CNC by applying each theory to water resources as a case.

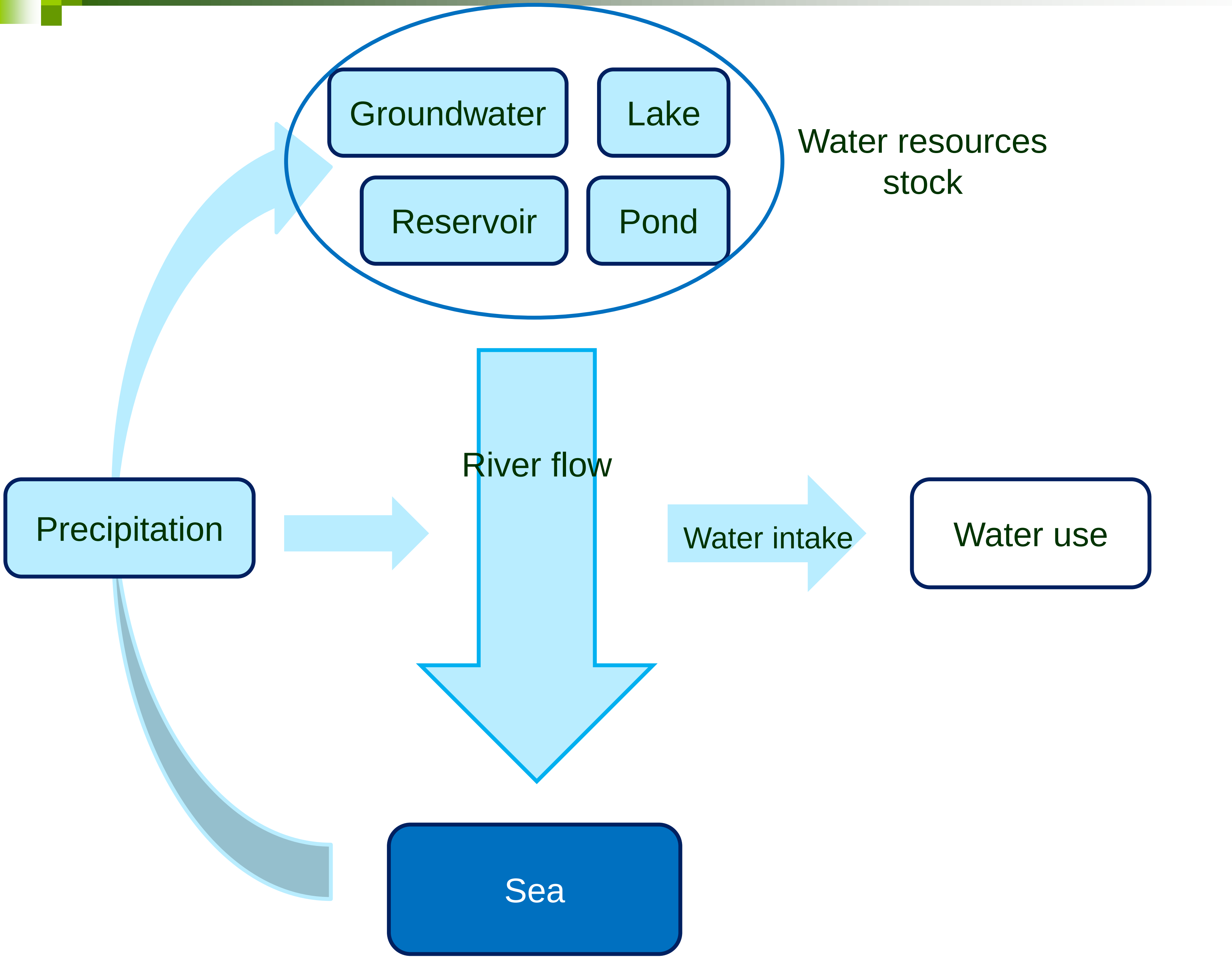
Four sustainability theories

- To investigate the underlying principles of CNC, this paper focuses on the following sustainability theories.



Summary of the CNC conditions in each sustainability theory

	Type of NC	Focus	Flow	Stock	Conditions of CNC
(1)Solow-Hartwick	Stock of resource input	Essentiality	X		• Without which the level of output will go to zero
(2) Daly	Stock of resource input	Essentiality		X	• Without which the level of output will go to zero
		Threshold		X	• Which has a threshold that will cause disasters or infinite loss of utility
(3) Pearce-Turner	Stock of resource/ environment	Technical substitutability	X		• Whose functions are not technically substitutable
(4) Ekins	Stock of resource/ environment	Technical substitutability	X	X	• Without which the important/ critical environmental functions are not performed
		Threshold	X		



Groundwater
Lake
Reservoir
Pond
Water resources stock
River flow
Precipitation
Water intake
Water use
Sea

Which part of water cycle deemed as critical?

	Type of NC	Focus	Flow	Stock	Examples
(1)Solow -Hartwick	Stock of resource input	Essentiality	x		• Water intake for agricultural production
(2) Daly	Stock of resource input	Essentiality		x	• Water resources stock
		Threshold		x	
(3) Pearce-Turner	Stock of resource/ environment	Technical substitutability	x		• River flow • Precipitation
(4) Ekins	Stock of resource/ environment	Technical substitutability	x	x	• River flow • Precipitation • Water resources stock
		Threshold	x		

Discussion

- The result shows that each theoretical framework recognizes different part of water cycle as critical.

	Flow			Stock
	Water intake	River flow	Precipitation	Water resources stock
(1)Solow-Hartwick	x			
(2) Daly				x
(3) Pearce-Turner		x	x	
(4) Ekins		x	x	x

Discussion

- Ekins' sustainability is most comprehensive.
  - i.e., Daly's sustainability and Pearce-Turner's sustainability are integrated.

- However, it does not take into account the part of "water intake" in the process of identifying CNC.

- If a society cannot adequately intake water from rivers, e.g., due to the underdevelopment of water infrastructure, water would become more critical.

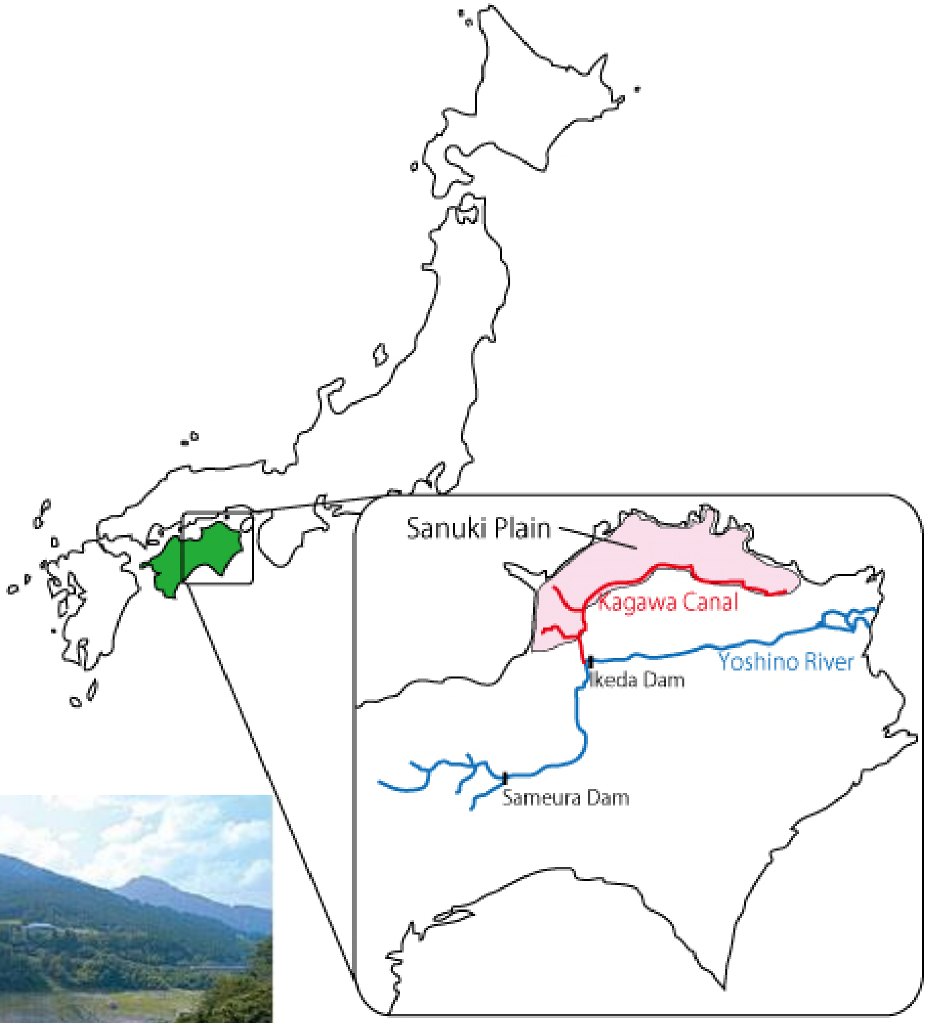
Discussion

- Solow-Hartwick's sustainability is offering the way of incorporating the importance of water intake by the standard of "essentiality", however, it is too strictly defined.
  - It checks whether the output decreases to zero if water intake is stopped.
- In the context of water resources, it would be more crucial to focus on whether water intake can satisfy water demand.
- The gap between water intake and water demand matters! (i.e., occurrence of drought)

The case of 1994 drought in Japan

- Farmers in the Sanuki Plain successfully adapted to the serious drought by conducting:
  - Water sharing
  - Labor increase
  - Traditional water use

➡ Determinants of water use



Conclusion

- Investigating the existing four sustainability theories, this paper examined how CNC can be captured in the existing sustainability theories.

- When applying them to the context of water resources, each theory recognizes the different part of water cycle as critical.
  - This might provoke a conflict between water resource users.

- It is important to focus on determinants of water use whether people can resiliently change their demand to meet the limit of water intake.
  - If a society cannot decrease their water demand, water may become more critical.
  - This implies that we should take into account the social context of natural capital (i.e., institution, labor, technology or knowledge) in the assessment of CNC.

Thank you for your kind attention!

If you have any comments, feel free to contact to:

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- Is river flow essential to production?
- Is water source essential to production?

- Essentiality
- Technical substitutability
- Threshold

Stock of resource input without the flow from which the level of output will inevitably go to zero.

Stock of resource input without which the level of output will inevitably go to zero.

Stock of resource input which has a threshold that will cause disasters or infinite loss of utility.

Stock of resource/environment from which the flows (i.e., environmental functions) are technically non-substitutable.

Stock of resource/environment without which the important/critical environmental functions are not performed.

Water as CNC

- In Solow-Hartwick's sustainability,
- In Daly's sustainability, the essentiality of NC is defined on the level of NC stock.

a) Production approach

- (1) Solow-Hartwick's sustainability
  - Purpose of SD: maintaining the level of the consumption
  - If the resource inputs are not "essential", we can maintain the positive level of outputs by obeying Hartwick's rule.
  - 基 ルールに従って人工資本への

ハートウィック・ルール

枯渇性資源から得られるレントを人工資本への投資に回す

↓

- 正の生産量の維持
- 各世代の消費量の均等化

ソロー＝ハートウィックのSD論に基づけば･･･

- 自然資本として捉えられる対象
  - 資源（生産要素）

- 代替可能性の認識
  - 生産要素のフロー
  - 資源の投入量＝0→生産量＝0

- CNCの条件
  - 生産要素のフローが代替不可能な自然資本

1. Solow-Hartwick's sustainability

- Optimal depletion of non-renewable resource model

$$\max W = \int_{t=0}^{t=\infty} U(C_t)e^{-\rho t}dt$$

$$s.t. \quad \dot{S}_t = -R_t, \quad \dot{K}_t = Q(K_t, R_t) - C_t$$

W: social welfare function, *U(Ct)*: aggregate utility, C_t: consumption, ρ: discount rate, S_t: non-renewable resource stock, R_t: depletion of non-renewable resources, K_t: man-made capital , $Q(K_t, R_t)$: production function

- SD is regarded as maintaining constant or non-declining consumption

1. Solow-Hartwick's sustainability

- "Essentiality" of non-renewable resources

$$R_t \text{ is essential if } Q(K_t, 0) = 0$$

- What is the condition determining "essentiality"?
  - CES production function

$$Q(K_t, R_t) = A(\alpha K^{-\rho} + \beta R^{-\rho})^{-1/\rho}$$

  - Cobb-Douglass production function

$$Q(K_t, R_t) = AK^{\alpha} R^{\beta}$$

A: technology, α, β : elasticity of output

$A>0$, $\alpha>0$, $\beta>0$, $\alpha+\beta=1$, $-1<\rho\neq0$

1. Solow-Hartwick's sustainability

- Conditions for SD
  - CES production function
    - R_t is essential if $0 < \rho < \infty \Leftrightarrow 0 < \sigma < 1$ $\left(\sigma = \frac{1}{1+\rho}\right)$
    - R_t is non-essential if $-1 < \rho < 0 \Leftrightarrow \sigma > 1$
  - Cobb-Douglass production function ($\sigma = 1$)
    - R_t is essential if $\sigma = 1$ and $\alpha \leq \beta$
    - R_t is non-essential if $\sigma = 1$ and $\alpha > \beta$
- Natural capital is captured as production inputs

How can CNC conceptualized in each sustainability theories?

分類	SD論	自然資本	代替可能性	CNCの条件
Production	(1) Solow–Hartwick's	資源ストック（生産要素）	生産要素フロー	• フローが生産に不可欠 • フローが代替不可能
	(2) Daly's		生産要素ストック	• ストックが生産に不可欠 • ストックが代替不可能
Function	(3) Pearce–Turner's	資源＋環境（生態系）	環境機能	• 各世代の効用の維持に不可欠 • 環境機能が代替不可能
	(4) Ekins		環境機能と効用	• 環境機能の維持に不可欠 • 環境機能が代替不可能

①どのような目的の下で利用するか
②どの部分の代替可能性を考えるか
③様々な理論的前提

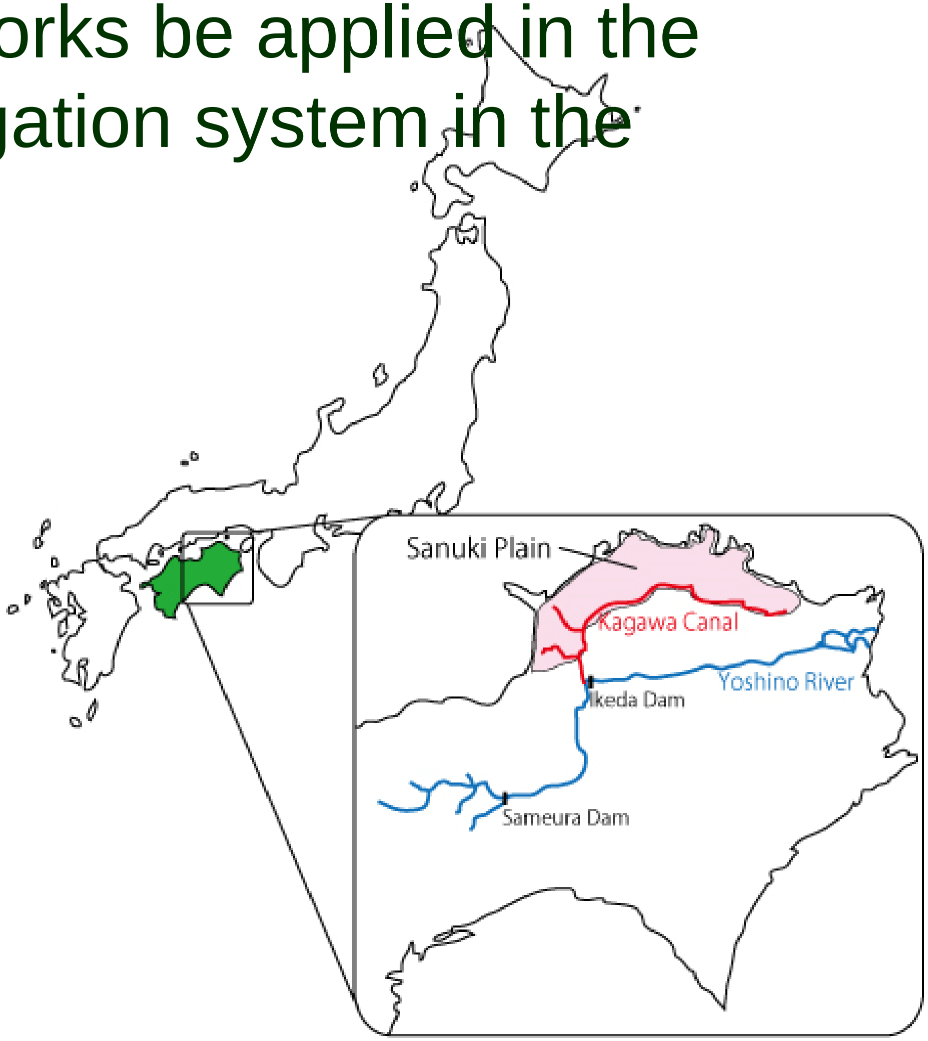
→ CNCの条件が変化

↓

代替可能性の「認識プロセス」への注目

Application to the Sanuki Plain, Japan

- How can these frameworks be applied in the context of the pond irrigation system in the Sanuki Plain?



Characteristics of the Sanuki Plain

- (1) Densely constructed local ponds
  - Due to the high scarcity of water, local ponds have been extensively constructed in the Sanuki Plain.
  - More than 10,400 (in 2000)
  - Density: 7.79/km^2 (in 2000)

http://www.jcca.or.jp/dobokuisan/japan/shikoku/manou.html

http://www.city.takamatsu.kagawa.jp/4868.html

Characteristics of the Sanuki Plain (cont.)

- (2) Water distribution through the Kagawa canal

Source : http://www.mizu.gr.jp/kikanshi/mizu_23/no23_g01.html

- Constructed in 1978
- Conveying water from Yoshino river…
  - 105 million m^3 per year for agriculture (30,700 ha)
  - 122 million m^3 per year for tap water
  - 20 million m^3 per year for industry

Drought in 1994

- A drought hit the Sanuki plain in 1994 and the stock of water resources in local ponds kept decreasing (some of them were depleted).

Drought in 1994

- Sameura dam (the source of Kagawa Canal water) also kept decreasing.
  - 29 June: 30% of water intake has been cut
  - 8 July: 60% of water intake has been cut
  - 16 July: 75% has been cut
  - July 24: water intake from the Sameura Dam stopped
  - Significant rainfall has occurred, however, the restriction of water intake was not totally lifted until November 11.

Source：