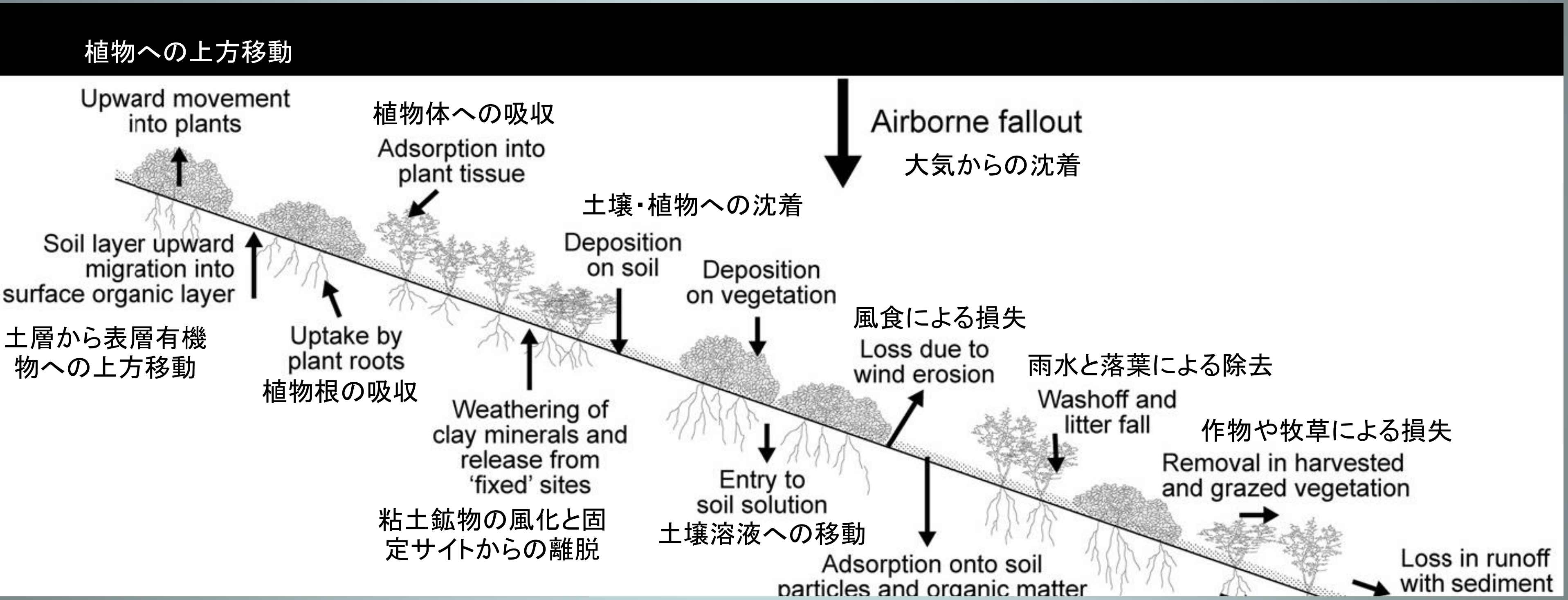
Movement of ^{137}Cs by water on hillslopes

斜面の水移動にともなう^{137}Csの動き

^{137}Cs pathways

^{137}Csの移動経路



植物への上方移動

植物体への吸収

大気からの沈着

土壌・植物への沈着

土層から表層有機物への上方移動

植物根の吸収

風食による損失

雨水と落葉による除去

作物や牧草による損失

粘土鉱物の風化と固定サイトからの離脱

土壌溶液への移動

土壌粒子や有機物への吸着

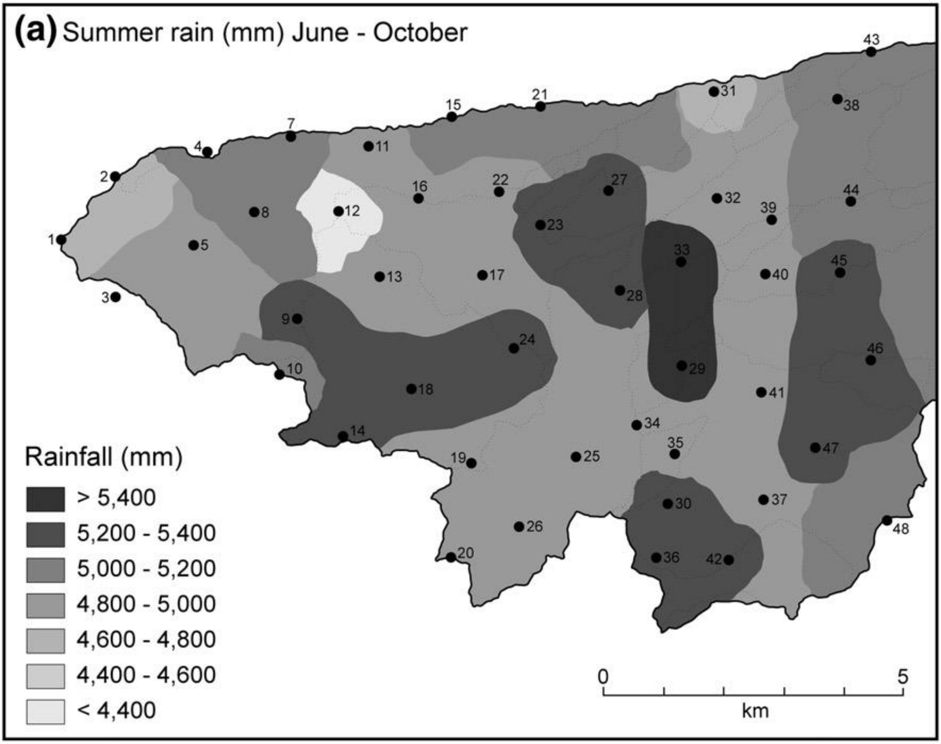
土砂流出に伴う損失

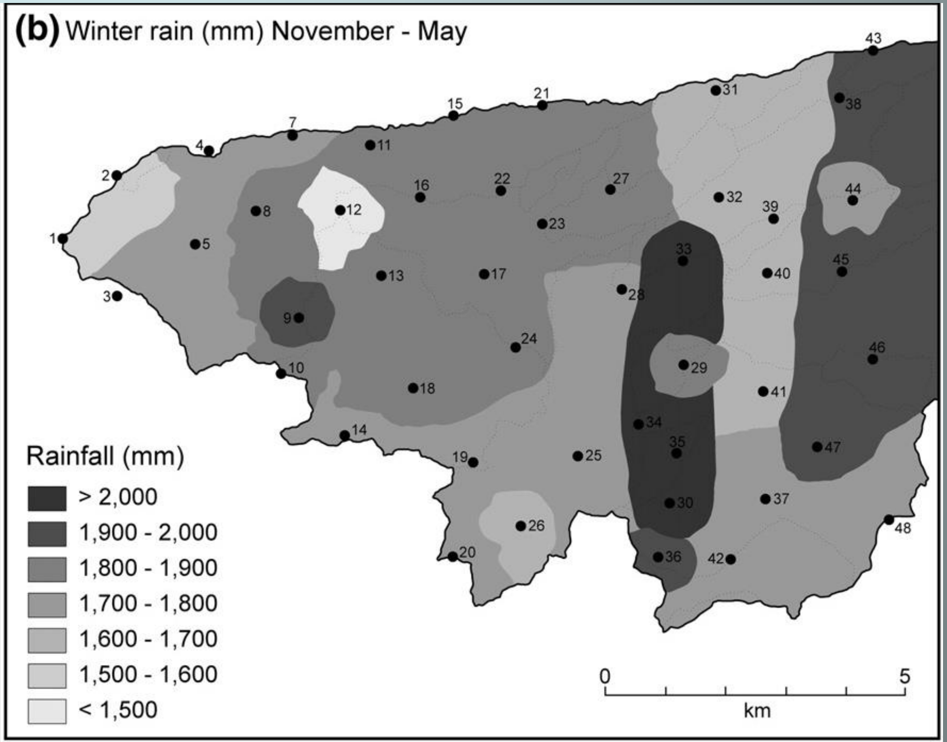
Key points

- Some fallout ^{137}Cs is adsorbed onto soil particles（吸着）
- The timing of the adsorption is variable depending on cycling through other pathways
- Even once adsorbed onto soil particles, it may be de-adsorbed and re-enter the other pathways
- IT’S COMPLICATED!

Both dry and wet deposition. Dry deposition favours deposition onto plants – and subsequent cycling. Wet deposition affected by spatial pattern of rainfall

※Dry deposition : 乾性沈着
Wet deposition : 湿性沈着





However,

I’m not going to talk about the these complications.

I’m going to talk about the processes of sediment movement by water on hillslopes. These processes will determine how and why ^{137}Cs is able to move from hillslopes into river channels, but rates of sediment movement do not tell you rates of ^{137}Cs movement.

3 basic processes of sediment entrainment and transport

（地面から剥離すること）

（運搬）

Entrainment and transport by raindrops

（雨滴）

Entrainment by raindrops and transport by shallow flow

（薄層流）

Entrainment and transport by shallow flow

All require water at the surface – so start by examining rainfall and infiltration

（浸透能）

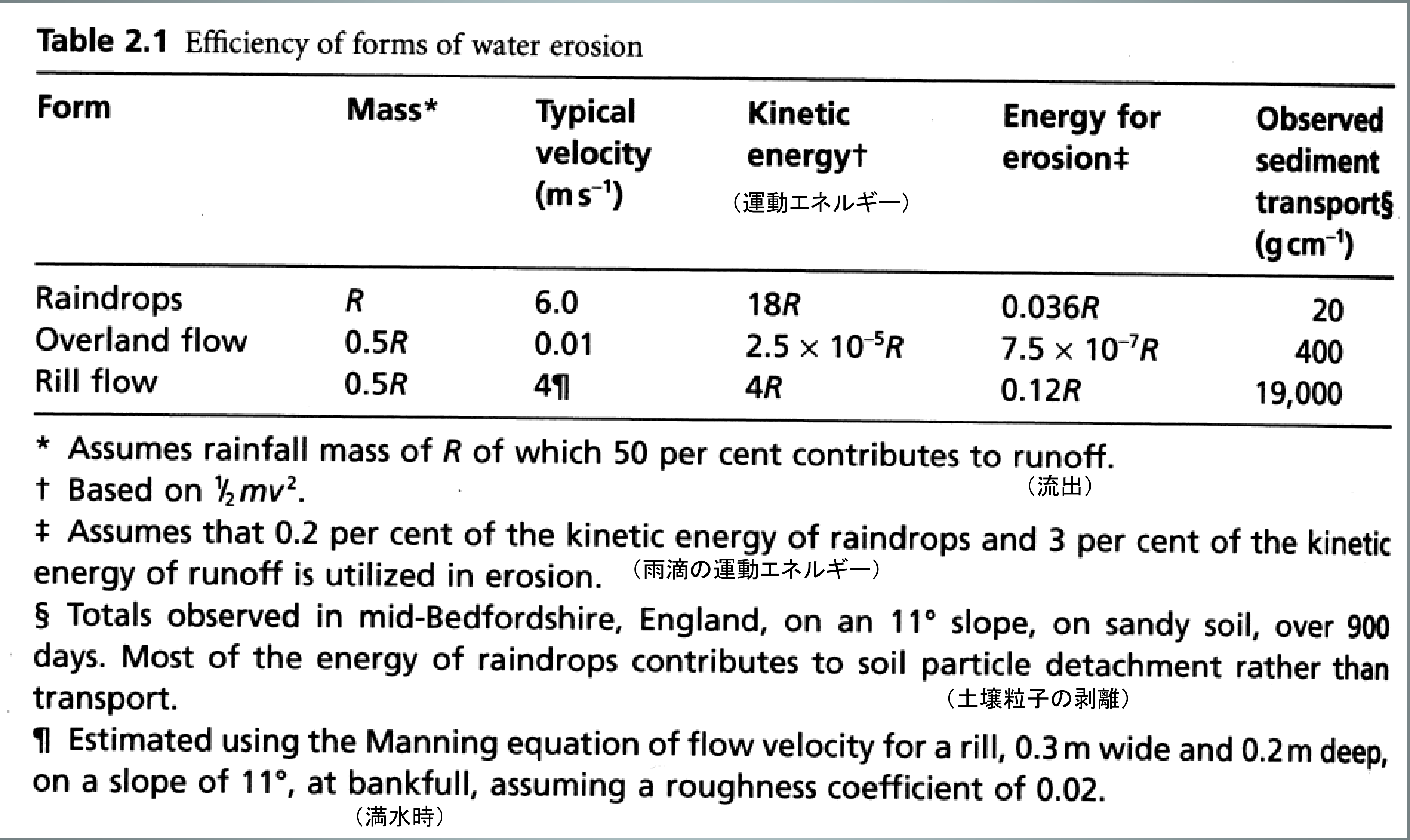


Table 2.1 Efficiency of forms of water erosion

Form	Mass*	Typical velocity (m s^{-1})	Kinetic energy† （運動エネルギー）	Energy for erosion‡	Observed sediment transport§ (g cm^{-1})
Raindrops	R	6.0	18R	0.036R	20
Overland flow	0.5R	0.01	$2.5 \times 10^{-5}R$	$7.5 \times 10^{-7}R$	400
Rill flow	0.5R	4¶	4R	0.12R	19,000

* Assumes rainfall mass of R of which 50 per cent contributes to runoff. （流出）

† Based on $\frac{1}{2}mv^2$.

‡ Assumes that 0.2 per cent of the kinetic energy of raindrops and 3 per cent of the kinetic energy of runoff is utilized in erosion. （雨滴の運動エネルギー）

§ Totals observed in mid-Bedfordshire, England, on an 11° slope, on sandy soil, over 900 days. Most of the energy of raindrops contributes to soil particle detachment rather than transport. （土壌粒子の剥離）

¶ Estimated using the Manning equation of flow velocity for a rill, 0.3 m wide and 0.2 m deep, on a slope of 11°, at bankfull, assuming a roughness coefficient of 0.02. （満水時）

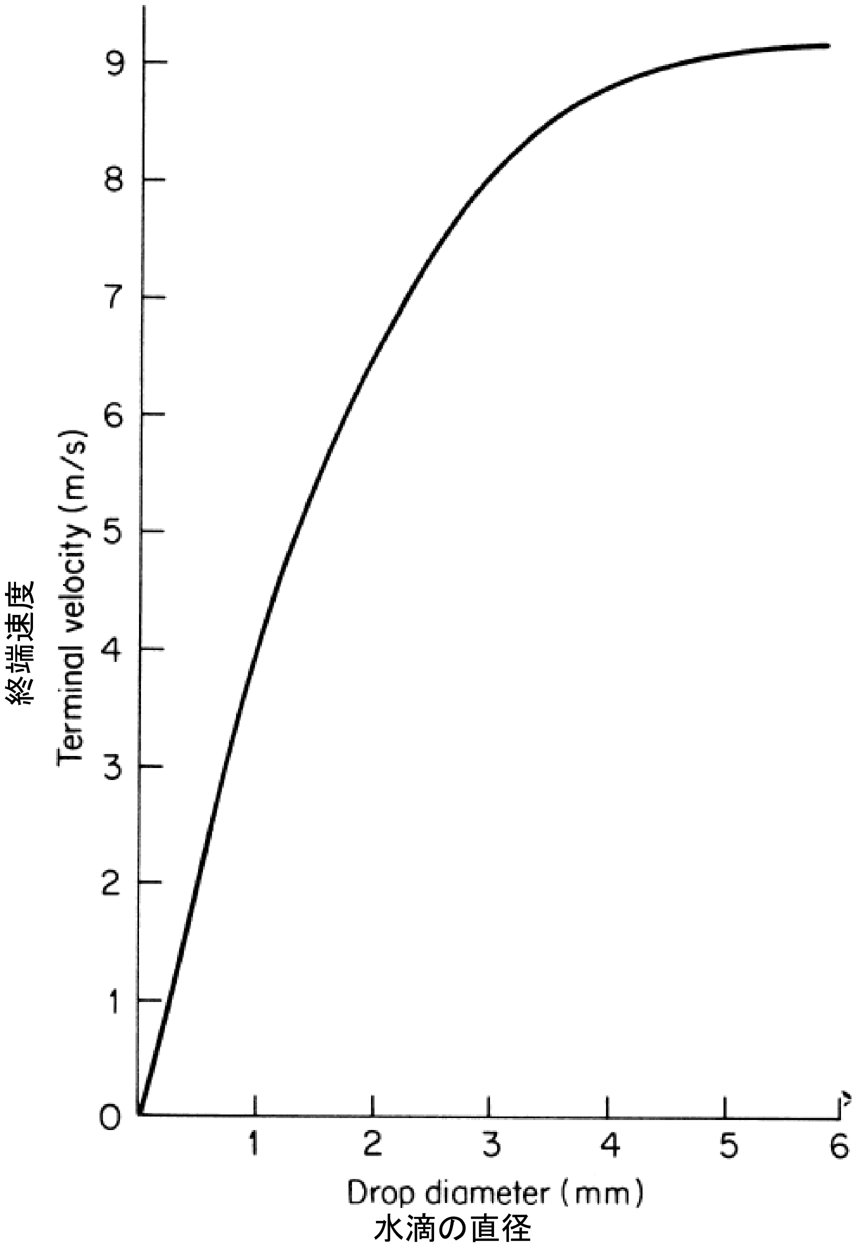


Figure 4.1. Terminal velocities of water droplets in stagnant air (after Gunn and Kinzer, 1949)

停滞空気

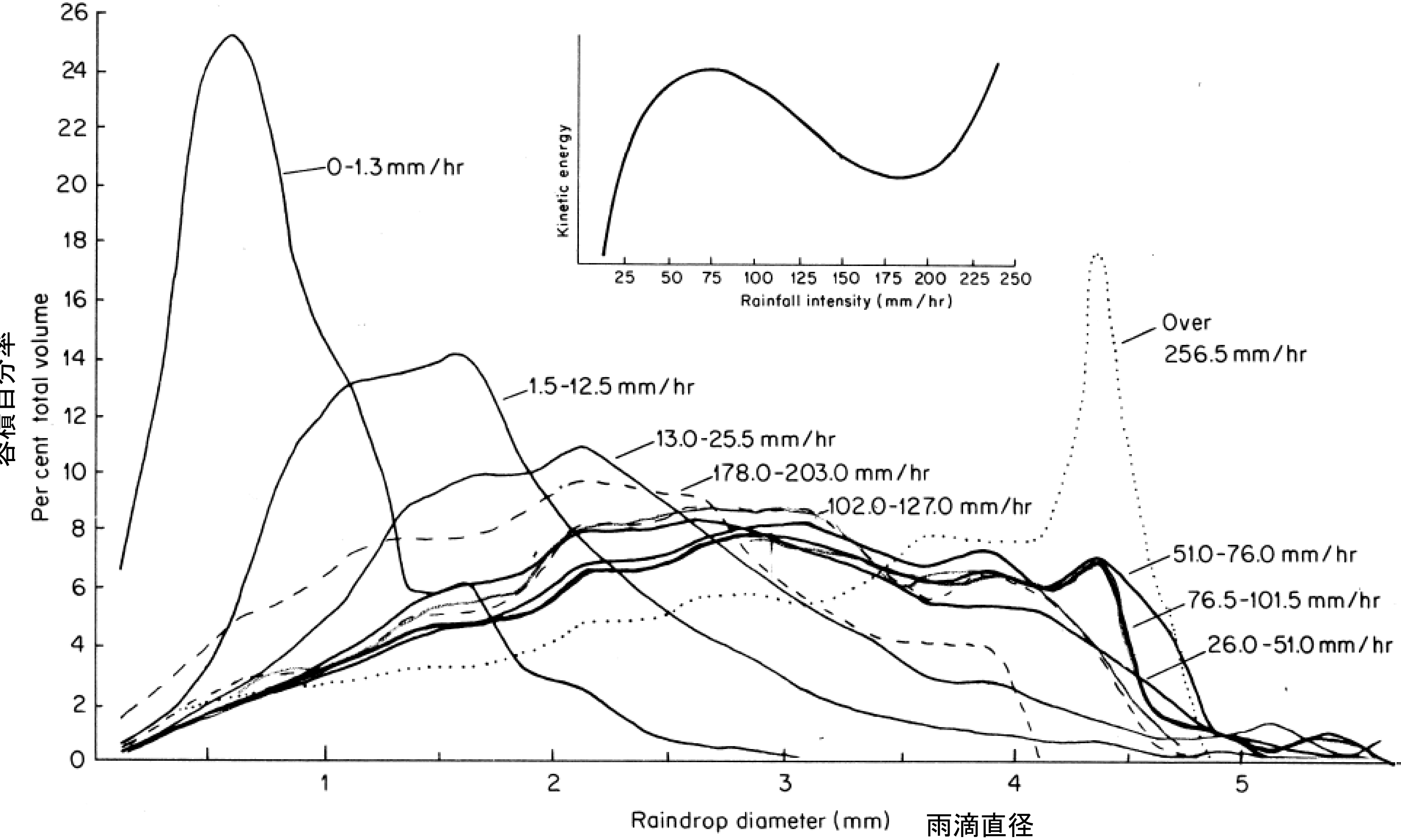
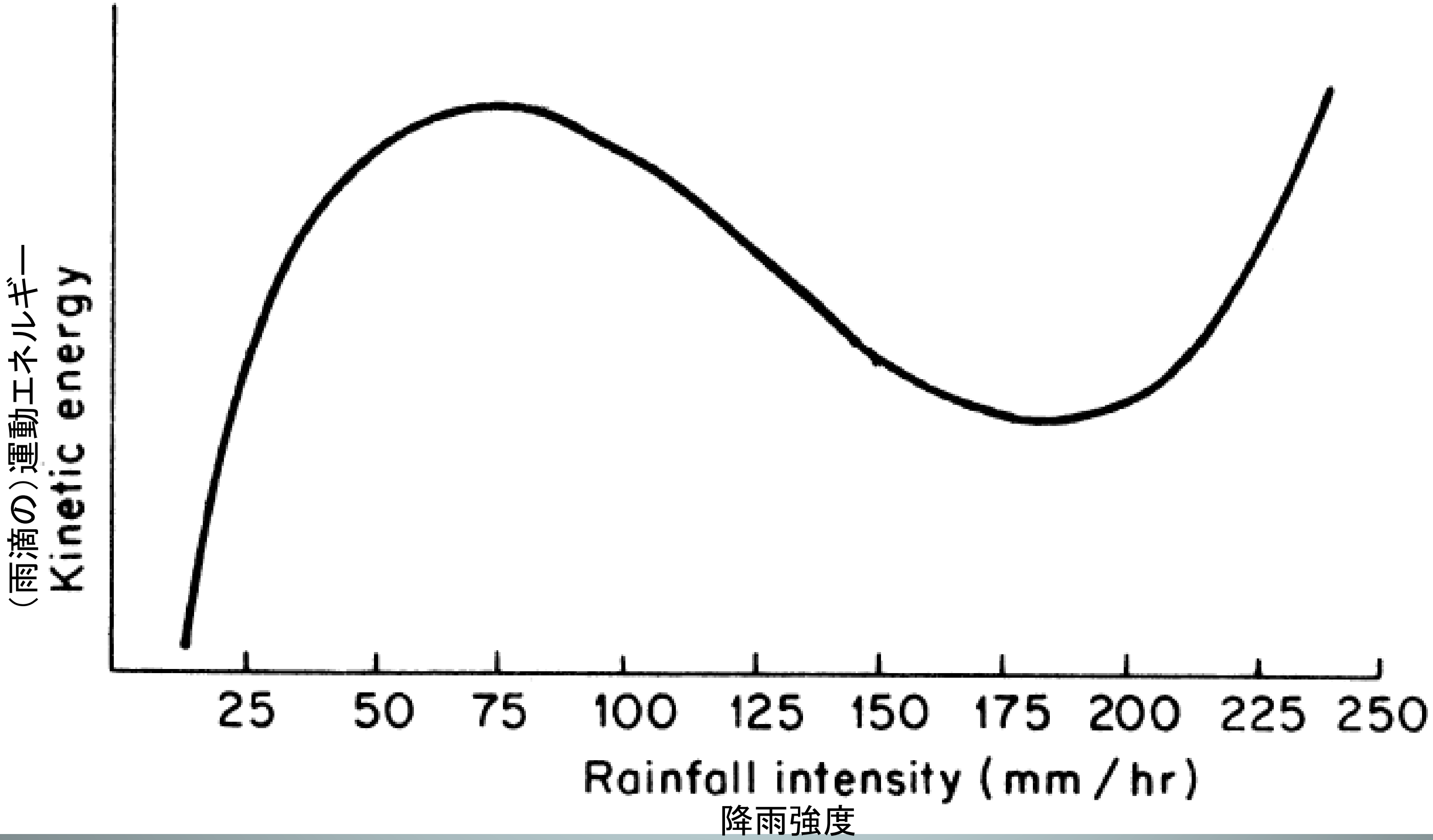


Figure 4.2. Raindrop size distribution and rainfall intensity (after Carter, *et al.*, 1974)

（降雨強度）


（雨滴の）運動エネルギー
Kinetic energy
25
50
75
100
125
150
175
200
225
250
Rainfall intensity (mm / hr)
降雨強度

Basis of relationship between rainfall intensity and kinetic energy:

For individual raindrop: $KE = \frac{1}{2} m v^2$

For storm KE, sum over all raindrops. According to Marshall & Palmer (1948), for a storm of intensity i, the number N of drops of size D is given by

$$N(D) = N_0 e^{-\Lambda D}$$

where

$$\Lambda = 4.1 i^{-0.21}$$

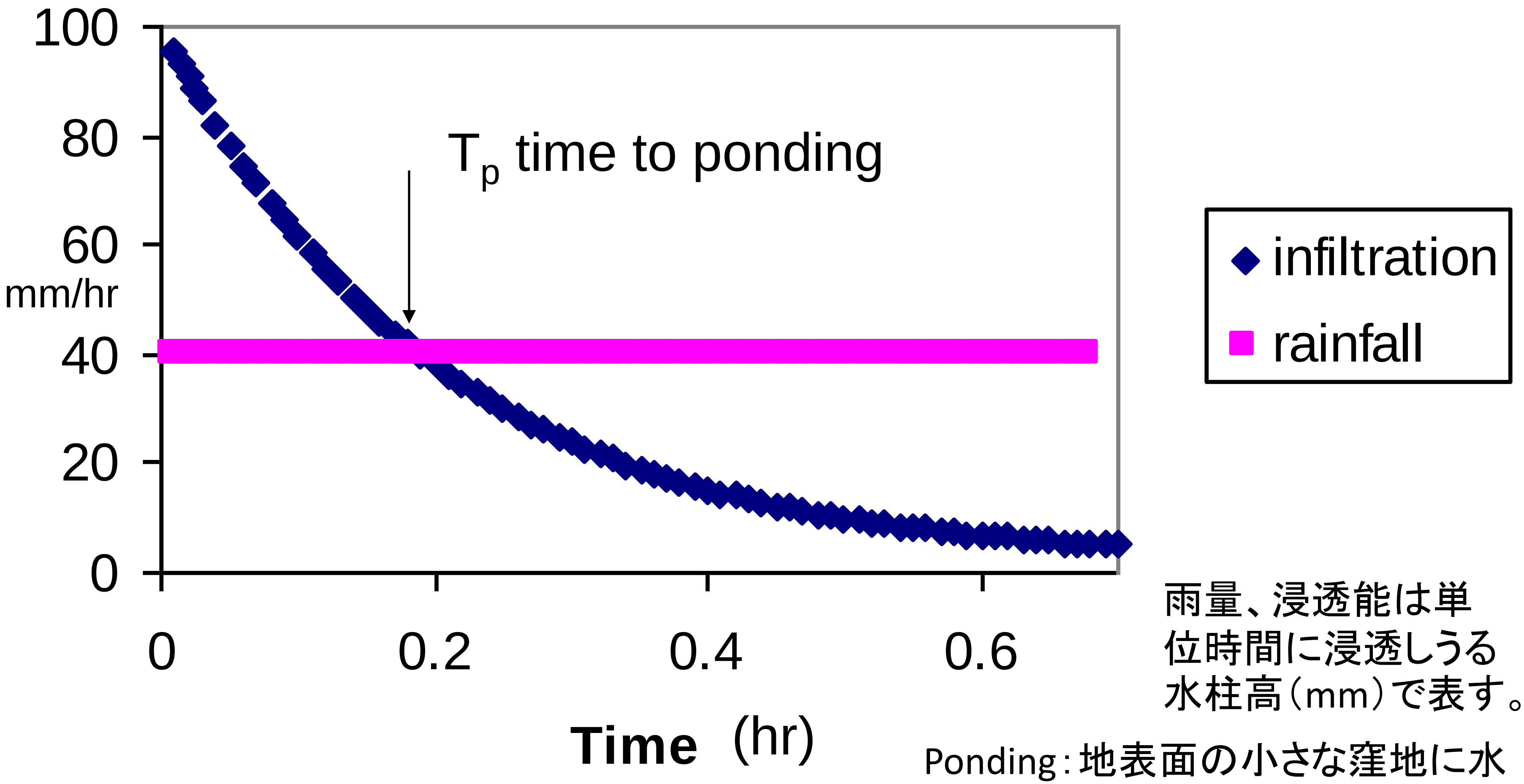
Why does drop size distribution (and hence KE) vary with rainfall intensity?

a) Processes of rainfall generation – cyclonic/ （サイクロン） convective （対流性）

b) Drop coalescence （癒合） and break-up

Infiltration

（浸透）



雨量、浸透能は単位時間に浸透しうる水柱高（mm）で表す。

Ponding：地表面の小さな窪地に水面が発生すること。窪地から水があふれると表面流が発生する。

- Horton infiltration equation:

（ホートン：人の名前）

$$f = f_c + (f_0 - f_c)e^{-kt}$$

Where f is maximum instantaneous infiltration rate; f_c is the limiting steady infiltration rate, assumed to be a constant for a given soil type; f_0 is the initial infiltration rate at the start of the storm (t=0); k is a positive constant of permeability for a given soil; t is time

（透水性）

Other equations for infiltration give similar exponential decay rates

e.g. Philip (1957)

$$f = A + Bt^{-0.5}$$

Where A ≈ f_c; and B ≈ f_0