Chapter III Investigation of channel heads

III-1: Methods

Distribution and topographic characteristics of channel heads were investigated in order to analyze the tendency of area-slope relationship in the channel heads of the investigated area. Dietrich and Dunne (1993) defined the channel head as '*the upstream boundary of concentrated water flow and sediment transport between definable banks*'. A channel is independent of the existence of stream flow.

Channels in the present study area are morphologically recognized with 'distinct traces of debris removal by water flow' (Figure 6). Both sediment and biological debris (twigs and leaves) remain on the slopes, while they are transported in the channel. The channels also have 'small banks' and structure of 'step sequences'. As described in the next section, topography of channel heads varies with the steepness (two types as shown in Figure 6).

Thirty-four channel heads were investigated (Table 2). Figure 7 indicates the distribution of channel heads, unchanneled valleys and source areas in the present study area (the flame is same as Figure 3). Here, each first-order basin including a channel head was numbered (C1, C3, and O11 – O62). As described later in detail, C1 and C3 basins are investigated watersheds for intensive hydro-geomorphic observations. The other basins were numbered from O11 to O62 in order of investigation, in principle, while a series of basin number includes lacked numbers for the convenience of investigation. Topography of the channel heads were surveyed in three times: (1) November in 2000 for C1 and O11 – O19 basins, (2) October in 2001 for C3 and O21 – O38 basins, and (3) June to July in 2003 for O51 – O62 basins. The channel head in each first-order basin was marked with H in the end of the basin number (e.g. C1H means the channel head of C1 basin).

Measured items on topographic characteristics of channel heads are illustrated in Figure 8. The locations of channel heads were verified in situ with an altitude meter, and were plotted on a base map of the 1:25,000-topographic map 'Shimotsuke-Ohgaki' issued by Geographical Survey Institute, Japan. Drainage area was measured on the 1:25,000-topographic map with graphic software (Canvas 8). Relative height, R_h, was obtained as the maximum difference in altitude within a source area. Local head-slope angle, θ_h, from the channel head to the point about 10 m upslope, and local channel angle, θ_c, from the channel head to the point about 10 m downstream were measured with a hand compass or a slope measuring devise, which is composed of a right triangle (hypotenuse of 1 m long) and a slope meter. Local head slope, S_h, and local channel gradient, S_c, were defined as $S_h = \tan \theta_h$ and $S_c = \tan \theta_c$, respectively.

In three channel heads, O32H, O34H, and O37H, the source areas were not determined because they are too small to express topographic convergences in the topographic map. The local head slope, S_h, and local channel gradient, S_c, in four channel heads, O38H, O56H, O57H and O58H, could not be measured due to high steepness of their channel heads. Local channel gradient, S_c, in the other three channel heads, O23H, O30H, and O33H, was not measured due to dangerous positions. Consequently, all topographic data were available in the other 24 channel heads (Table 2).

III-2: Type of channel heads

The channel heads in the present study area have wide ranges of source area, A (530 – 16,900 m^2), local head-slope angle, θ_h (23° – 50°), and local channel angle,

θ_c (20° – 44°) (Table 2). The minimum source area would be smaller than 530 m^2, since the source areas with < 500 m^2 could not be measured. Whereas most channel heads have θ_c smaller than θ_h, two exceptional channel heads, O35H and O52H, have θ_c slightly steeper than θ_h.

Morphometric characteristics of channel heads generally vary with gradient. Thus, channel heads are classified into two types based on local channel angle, θ_c: gentle (θ_c < 30°) and steep (θ_c ≥ 35°) channel heads are referred to as Type G and Type S, respectively (Figure 6). Channel heads with intermediate angles (30° ≤ θ_c < 35°) are considered as the transitional type.

Photo 2 shows the hollow of a typical Type-G channel head (O16H). In this channel head, local channel angle (20°) is relatively small and source area (7,200 m^2) is relatively large. This hollow appears to be filled with gravels, which would be supplied from behind bedrock cliffs. In general, first-order basins with Type-G channel heads have hollows filled with sediment (Figure 6). Gradient changes gradually from slope to channel in most Type-G channel heads.

Photo 3 shows a typical Type-S channel head (O38H) with a steep bedrock channel surrounded by bedrock cliffs. Local head slope and source area in this channel head could not be measured due to high steepness. The whole section consists of bedrock channel lacking sediment. In general, Type-S channel heads are located at the base of bedrock cliffs, and have steep bedrock channels (θ_c ≥ 35°) (Figure 6). Gradient changes abruptly from slope to channel in some Type-S channel heads.

Shallow landslides are only sporadic even in steep slopes and channel heads in the investigated area. Only five Type-S channel heads (marked with LS in Table 2) have small scarps of shallow landslides, while the scarps have smaller size (< 5 m in width) than those in general granitic hillslopes (e.g. Onda, 1992). Most of the steep slopes in the investigated area consist of bedrock cliffs without scars of shallow landslides.

III-3: Area-slope relationship

Montgomery and Dietrich (1988, 1989) revealed that an inverse correlation between source area, A, and local head slope, S_h, immediately above a channel head. They reported the relationship of $A = 1978\ S_h^{-1.65}$ ($R^2 = 0.75$) in Tennessee Valley, Marin County, California (annual rainfall: 760 mm; bedrock: sandstone, chert and greenstone). Relationship between slope and source area was analyzed to confirm whether or not a similar relationship is obtained in the preset study area. Figures 9 and 10 show the relationship between A and S_h, and relationship between A and S_c (local channel gradient) respectively. These plots indicate that A decreases with increasing S_h or S_c. The simple least squares regression analyses yield following equations:

$$A = 972\ S_h^{-2.82} \qquad (R^2 = 0.71) \qquad (1)$$

$$A = 747\ S_c^{-2.47} \qquad (R^2 = 0.56) \qquad (2)$$

where the unit of source area, A, is m^2. The source areas in the present study area are smaller than those in the Tennessee Valley (Montgomery and Dietrich, 1989) for the same slope condition. The difference in these regression curves should be derived from the differences in bedrock conditions and climatic factors.