This case study explored forest resource-use patterns to understand villagers' dependency on forests in four temperate villages situated in two forested sites in Garhwal Himalaya: Mandal and Khalla in the Mandal area, Chamoli District, and Chaundiyar and Dikholi in the Chaurangikhal area, Uttarkashi District. Although the literacy rate in the villages was quite high, due to lack of employment opportunities people still invariably depend on forests for their livelihood. In all the study villages more than 75% of fodder and fuelwood were extracted from the forest. The pressure exerted by human and bovine populations, coupled with unsustainable management policies, has resulted in the destruction of forest cover and ecological degradation. Agriculture (which is 70% rainfed in the Mandal area and 90% rainfed in Chaurangikhal) and employment as laborers were the main occupations of people in the study areas; in addition, remittance income (8.6% in the Mandal area and 21.3% in Chaurangikhal) and dairy farming accounted for a major portion of total household income. The study revealed a positive relationship between income and livestock population (0.995), which reveals the strong role of animal husbandry in the rural economy. The equally positive relationship between income and fodder consumption (0.930) can be attributed to extraction of large quantities of fodder to sustain dairy farming for commercial purposes. The correlation between income and fuelwood consumption was found to be negative (−0.882), the likely reason being poor economic conditions, leading to dependency on the forest for fuelwood as a free source of energy.

Keywords: Forest use; livestock; fuelwood; fodder trees; income sources; poverty; Garhwal Himalaya; India.

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above mean sea level, often called the agricultural or populated zone; pressure on forests is at a maximum in this range (Tewari et al. 2003). Because of limited employment opportunities in the rural areas of Garhwal Himalaya, people either migrate to the plains in search of jobs or depend solely on forests and small-scale agriculture for their livelihood.

This article presents a case study from Garhwal Himalaya that deals with the links between the socioeconomic status of people and forest resource-use patterns. It explores the pattern of energy consumption, the relationship between income and forest use, and the causes of pressure on forests for various products. It concludes with suggestions regarding possible action to prevent further forest degradation.

Material and methods

The study areas lie in the temperate zone of Garhwal Himalaya in Uttarakhand State in India (Figure 1). The study was carried out in 4 villages, 2 in the Mandal area (Mandal and Khalla), which lies at latitude 30°27.560′N and longitude 79°15.234′E between 1500 m and 1550 m in the Chamoli district, and 2 in the Chaurangikhal area (Chaundiyar and Dikholi), which lies at latitude 30°27.906′N and longitude 79°15.303′E between 1600 m
and 1750 m in the Uttarkashi district. Details of the climate and cropping patterns in these study areas are shown in Table 1.

The climate in the study areas can be divided into three distinct seasons, namely summer (April–June), rainy (July–September), and winter (November–February). The rainfall pattern in the region is largely governed by the monsoon rains (July–September), which account for about 60–80% of the total annual rainfall. The vegetation in the study areas is both natural and man-made. Khalla and Mandal villages are situated at the base of natural temperate mixed broad-leaved forests, whereas Chaundiyar and Dikholi are situated between pure pine forests. The mixed broad-leaved forests at both sites have more or less similar species composition (Table 2).

Structured and pretested questionnaires were used to interview approximately 30% of the total households in each village (a total of 108 in 4 villages; Table 1). These questionnaires were based on the requirements of the study and on information extracted from general discussions with villagers to gather information from each social caste, economic level, gender, and age. We also used different ways of collecting precise, quantitative data on income and income sources: questionnaires, personal observation, and discussions with gram pradhans (heads of village legislative councils). The head of each sample household was interviewed. The data collected for the study included general information about each household, such as literacy level, family size, landholding, number of animals per family, sources of income, occupation, sources of energy, extraction of non-timber forest products, and so on.

To estimate the amount of fuelwood and fodder consumption per day per household, 10% of the households per village (a total of 34) were surveyed in the 4 villages, and their consumption amounts were noted for 7 consecutive days in 3 different seasons: summer, rainy, and winter. The families surveyed were chosen to include equal representation from all economic classes and family sizes. To understand pressure on individual forest tree species, we asked about villagers’ preferences for various purposes such as fuelwood, fodder, agricultural implements, household articles, and other uses; a maximum of 10 points was given for each use. This information was further verified by personal observations. All points were combined to give a final ranking for each tree species. The order of preference for all trees was subsequently ranked in descending order.

**Results and discussion**

**Socioeconomic observations**

The average family size varied between 5.3 persons per household in Chaundiyar and 5.8 persons per household in Khalla (Table 3). The sex ratio (females/thousand males) ranged between 862 in Chaundiyar and 1136 in

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**Table 1** General climatic and agricultural details for the study areas.

| Study area      | Climate data (1998–2007) | Cropping pattern for both study areas | Common leguminous crops |
|-----------------|--------------------------|--------------------------------------|-------------------------|
|                 | Mean annual maximum      | Mean annual minimum                  |                         |
|                 | temperature$^a$          | temperature$^a$                       |                         |
|                 |                          | Mean annual rainfall$^a$              |                         |
| Mandal          | 16.41 ± 3.60°C           | 6.14 ± 1.98°C                        | 2044.47 ± 476.01 mm     |
| Chaurangikhal   | 18.51 ± 3.70°C           | 5.71 ± 1.81°C                        | 1825.39 ± 417.54 mm     |

$^a$Source: Uttarakhand Forest Department.
| Altitude (masl) | Distance from villages | Tree species found at various altitudes (species in bold are dominant species) | Types of resource use (anthropogenic disturbances) |
|----------------|------------------------|---------------------------------------------------------------------------------|--------------------------------------------------|
| 2700–2900      | 7–8 km                 | Abies pindrow, Lyonia ovalifolia, Quercus semecarpifolia, Rhododendron arboreum, Sorbus cuspidata | LTL, LG, LSC, LTL, LG, ENTFP                        |
| 2500–2700      | 6–7 km                 | A. pindrow, Acer acuminatum, Aesculus indica, Diospyros montana, L. ovalifolia, Neolitsea pallans, Persea duthiei, Quercus floribunda, R. arboreum | LG, LTL, LSC, LTL, LG, ENTFP                       |
| 2300–2500      | 5–6 km                 | A. acuminatum, A. indica, A. pindrow, B. alnoides, Corylus jacquemontii, L. ovalifolia, P. duthiei, Q. floribunda, R. arboreum, T. baccata | LG, LTL, HSC, HTL, LG, ENTFP                      |
| 2100–2300      | 4–5 km                 | A. indica, A. pindrow, A. spectabilis, B. alnoides, B. wallichiana, C. viminea, D. montana, Daphniphyllum himalense, Doedicademia grandiflora, Euonymus tingens, Fraxinus micranthta, Juglans regia, L. ovalifolia, N. pallans, P. duthiei, Q. floribunda, R. leucotrichophora, R. arboreum | LSC, LTL, LG, HSC, HTL, LG                         |
| 1900–2100      | 2.5–4 km               | A. nepalensis, B. alnoides, C. viminea, D. himalense, D. montana, Ilex dipryena, L. ovalifolia, N. pallans, P. duthiei, P. pashia, Q. leucotrichophora, R. arboreum, S. paniculata, Ulmus wallichiana | LSC, LTL, LG, HSC, HTL, HG, ENTFP, RT, CF         |
| 1700–1900      | 1.5–2.5 km             | A. nepalensis, B. alnoides, C. viminea, Cupressus torulosa, D. himalense, D. montana, F. micranthta, L. ovalifolia, P. odoratifissima, P. roxburghii, Pyrus pashia, Q. leucotrichophora, R. arboreum, U. wallichiana | LSC, HTL, HG, HG, HSC, HTL, RT, CF                |
Mandal village. This difference can be attributed to lack of employment, which has led to migration of the male population from Mandal area to other areas in search of jobs. The literacy rate was above 80% in all 4 villages; most of the people were educated between grades 5 and 10 in Chaurangikhal area and above grade 10 in the Khalla, Mandal, and Dikholi villages. Few people were uneducated, and most of those were older. Although the literacy rate was very high, most people were unemployed because of a lack of employment opportunities. The villagers therefore still relied for their sustenance on rainfed agricultural land and forests.

The average cultivated land at both sites was less than 0.5 ha (Table 3); therefore, production was supplemented from the adjacent forest ecosystem. A positive relationship (0.784) between income and landholdings (Table 4) points to the major role of agricultural land in the economy of hill people. More than 90% of the agricultural fields in the Chaurangikhal area and about 70% in the Mandal area were rainfed. Approximately half of the houses in all the villages were made of cement, and the rest were a traditional type made of slate (pathsals), wood, and straw. Mainly traditional stoves (chullhas) with smoldering fuelwood were used for cooking. Because of the smoke produced by fuelwood and lack of proper ventilation in the houses, women generally face problems of suffocation and suffer from swollen eyes, loss of vision, bronchitis, and tuberculosis.

Mean monthly income and sources of income
The mean annual income in Indian national rupees ranged between Rs 17,895 (US$ 376) per household in Dikholi village and Rs 49,727 (US$ 1044) per household in Khalla village (Table 3), which is higher than the Below Poverty Line limit defined by the government of India for rural areas (Rs 12,000; US$ 252). The main occupation in all 4 villages was agriculture, which was practiced at a small scale on terraced farms and was not sufficient to feed an entire family for the year. Few vegetables and fruits from agricultural land were sold on the open market to earn cash income. Employment as a laborer was the second-largest source of income for the villagers. People worked in Gramin Rozgar Yojna and other welfare schemes run by the government, and they sometimes worked as laborers in the private construction sector. Dairy production was the third-largest source of employment in Mandal valley. Remittance income sent by people who had migrated to other places also accounted for a large portion of income in the Chaurangikhal area (21.3%), whereas in the Mandal area it was just 8.6% (Figure 2). This is because most of the men in the Chaurangikhal area are nomadic shepherds and migrate to higher altitudes during the summer and rainy season. They earn most of their income while residing outside their traditional villages.

Dairy products were sold to private agencies that collect them and sell in cities. Other sources of income were poultry, goat rearing, government jobs, government pensions, and extraction of minor forest products (Figure 2). A negative relationship between income and literacy level (−0.946) was recorded (Table 4), which is very rare and can be directly attributed to a lack of employment among the educated people in the area. This increases people’s dependency on agriculture and forest resources for income from which they earn substantial money, although agricultural work does not necessarily require educated people.
Almost everywhere in the mountains, agriculture is by and large based on livestock. Mountain communities are fully dependent on natural resources, livestock, and traditional agriculture; mountain agriculture is a socioeconomic symbiosis of crop, livestock, production, and manpower. In this type of system, besides human activities, livestock play a crucial role in strengthening the economy. Livestock are considered a capital asset. In addition, livestock provide gainful employment to a large section of the population throughout the year.

Common livestock domesticated by people in the study region are cattle, buffalo, sheep, goats, horses, ponies, and poultry. Among Hindus, only the meat of goats and chickens is eaten, and these animals are often sold to earn income, whereas large animals are rarely sold.
and hence are kept as a source of wealth. The major fodder resources are crop residues, leaves from trees, ground flora in forested areas, and dried grasses, which are stored on treetops in heaps and used as feed during lean periods when little fodder is available. The forest is the major source of leaf fodder and bedding material for livestock in the area.

Most of the families in the study areas owned livestock. Fodder consumed per household per day was 40.0, 40.5, 31.6 and 27.2 kg in Mandal, Khalla, Chaundiyar, and Dikholi villages, respectively (Table 3). This difference in fodder consumption per household between the Mandal and Chaurangikhal areas is due to the higher number of livestock in the Mandal area. Women in the study area spent about 1.5 to 3.5 hours daily to collect fodder from forested areas, which was the major portion of their everyday activity. In the Mandal valley, approximately 86% of the total fodder was being extracted from the forest, and the figure was 81% for the Chaurangikhal area.

All the animals graze in forestland, even up to an elevation of 2900 m, which harms the ground flora and impedes regeneration of dominant tree species in the area. In the Himalayan region, the prevailing opinion is that grazing is detrimental to forests. Forest grazing is frequently blamed for slow regeneration, poor forest conditions, and, in extreme cases, causing potential ecological disasters (Roder et al 2002). Negative effects on forest ecosystems attributed to forest grazing include loss of species diversity due to selective browsing, soil erosion, depletion of nutrients, soil acidification due to removal of biomass, compaction of topsoil and formation of hydromorphic humus, and damage to tree roots that facilitates root rot (Glatzel 1999). Uncontrolled grazing and overstocking of livestock prevent regeneration of the tree cover to some extent (Kumar and Shahabuddin 2005), but Ives (2006) has stated that its negative impact on land use in the Himalayas may be overstated.

The number of animals varied according to economic and social conditions in the villages. As dairy farming was one of the major occupations in the Mandal area, it accounted for a higher number of animals per households (5.6 in Mandal and 5.8 in Khalla) compared with the Chaurangikhal (3.7 in Chaundiyar and 3.5 in Dikholi) area (Table 3). A significantly positive (0.995) relationship was recorded between the number of livestock and the

| TABLE 4 | Pearson’s correlation coefficients between different parameters. |
|---------|---------------------------------------------------------------|
| Parameter | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1. Fodder consumed/household | 1.000 | | | | | | | | | |
| 2. Income/family | 0.930* | 1.000 | | | | | | | | |
| 3. Number of animals/household | 0.948* | 0.995** | 1.000 | | | | | | | |
| 4. Fuelwood consumed/household | -0.991** | -0.882* | -0.913* | 1.000 | | | | | | |
| 5. LPG consumed/household | 0.771 | 0.888* | 0.909* | -0.751 | 1.000 | | | | | |
| 6. Kerosene consumed/household | -0.240 | -0.487 | -0.395 | 0.108 | -0.230 | 1.000 | | | | |
| 7. Average family size | 0.393 | 0.625 | 0.638 | -0.363 | 0.888* | -0.212 | 1.000 | | | |
| 8. Sex ratio (females/1000 males) | 0.923* | 0.829 | 0.881* | -0.954** | 0.840 | 0.082 | 0.531 | 1.000 | | |
| 9. Literacy level | -0.780 | -0.946* | -0.910* | 0.695 | -0.801 | 0.734 | -0.624 | -0.605 | 1.000 | |
| 10. Landholding/family | 0.638 | 0.784 | 0.811 | -0.624 | 0.981** | -0.151 | 0.952* | 0.763 | -0.706 | 1.000 |

* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.
**FIGURE 2** Share of different sources of income in total household income in the study areas.

![Bar chart showing the share of different sources of income in total household income in the study areas.](image)

- **Source of income**
  - Agriculture
  - Labor employment
  - Dairy production
  - Poultry/goat rearing
  - Government job/pension
  - Migration income
  - Minor produce

- **% contribution**
  - Mandal area
  - Chaurangikhel area

**FIGURE 3** Heaps of fuelwood stacked for the winter season. (Photo by Sumeet Gairola)

![Photo of fuelwood heaps](image)
income per household, implying the strong role of animal husbandry in the rural economy of the study area.

**Pattern of energy consumption**

Fuelwood is the most common and primary energy source among rural populations in developing countries (Allen et al. 1988), and is used for cooking and also to heat rooms and water during the winter season. Other forms of commercial energy are beyond the reach of ordinary people because of poor socioeconomic conditions, lack of communication, high prices, and limited supply in inaccessible mountain areas (Chettri et al. 2002). It has been reported that 54% of the total global wood harvest is for fuel (Nautiyal and Kaechele 2008). Hence, fuelwood plays a major role in the progression of forest degradation.

In all the study villages, 100% of the families use wood as the chief source of fuel for cooking and heating. As all the villages are situated in the temperate zone, where it is usually cold, villagers extract wood for heating and cooking throughout the year. Collection of fuelwood from forests and private lands requires at least 2 to 4 hours of work every day in the study areas. The villagers travel 2 km in the Mandal area to 6–7 km in the Chaurangikhal area every day to collect fuelwood from the forest. In the Mandal valley, approximately 91% of fuelwood is collected from the forest, and the rest is collected from private lands; for the Chaurangikhal area, 75% of the fuelwood is collected from the forest (Table 3). Reasons for less forest wood collection in Chaurangikhal area could be linked to the greater distance of the forest from the village.

Average fuelwood consumption per household per day was recorded as 11.6, 13.1, 21.0, and 24.6 kg for Mandal, Khalla, Chaundiyar, and Dikhali villages, respectively. Stacks of fuelwood were collected during summer and stored for the winter season, when snowfall is high and accessibility to the forests at higher altitudes is minimal (Figure 3). Average liquefied petroleum gas (LPG) consumed per household per year was 56.8, 68.4, 31.2, and 44.0 kg in Mandal, Khalla, Chaundiyar, and Dikhali villages, respectively. In the study villages, LPG is occasionally used for cooking and mainly for preparing tea or quick food. Other sources of energy used in the area include kerosene oil, which is used mainly for lamps.

Other fuel types, such as crop residues and dung cakes, were not used in any of the villages studied. Dung cakes were not used as fuel for 2 reasons: (1) fertilizers are very rarely used in the agricultural fields, and because dung is the main source of manure, it is therefore required in large quantities; and (2) fuelwood is easily available at no cost and is simple to use compared with dung cakes. Whereas crop residues are either used as fodder or bedding material for livestock, a sod and dung combination constitutes the compost manure for agricultural fields.

A significant negative relationship (−0.882) between fuelwood consumption and income has been recorded in these villages, which shows that poor people are more dependent on forests for fuelwood as a source of energy (Table 4). A negative relationship (−0.751) was recorded between LPG and fuelwood consumption. A study by Nautiyal and Kaechele (2008) also showed a dramatic change in per capita fuelwood consumption in the villages where people are using LPG. A significantly positive relationship (0.888) between LPG consumption and income was recorded (Table 4), which suggests that greater purchasing capacity will reduce pressure on forests from fuelwood extraction and help people to adopt alternative sources of energy, such as LPG, kerosene, and solar energy. It is evident from Table 3 that the consumption of fuelwood per household in the Mandal valley was lower compared with the Chaurangikhal area, and consumption of other sources of energy, such as kerosene and LPG, was higher. This was mainly because economic conditions in the Mandal valley are better than in the Chaurangikhal area. Therefore, the villagers in Mandal area have more capacity to purchase LPG or kerosene and the supply of LPG and kerosene is regular. Also, the Mandal forest is part of the reserved forest; therefore, laws are strictly enforced and extraction of wood is difficult.

**Pressure on forests**

The Mandal forest is very dense and diverse compared with the Chaurangikhal forest (Table 2). We recorded 38 tree species in the Mandal forest and 18 tree species in the Chaurangikhal forest. Villagers in both study areas use wild and agroforestry tree species to fulfill their various needs. In the Mandal area, the villagers preferred 24 tree species (14 tree species in Chaurangikhal) for a variety of purposes. As these species were easily accessible, pressure on them was enormous (Tables 2 and 5).

*Quercus leucotrichophora*, *Q. floribunda*, *Q. semecarpifolia*, *Abies pindrow*, *Ainhus nepalensis*, *Pinus roxburghii*, *Rhododendrum arboreum*, *Betula alnoides*, and *Lyonia ovalifolia* are the fuelwood species the villagers prefer because they have high calorific values and are easily available and accessible (Table 5). As shown in Table 2, pressure on forests growing in the vicinity of the villages (within a 5-km range and between 1500 m and 2300 m) is high. In *P. roxburghii* forest, resin tapping and regular forest fires are the major causes of destruction, whereas in *Quercus* forests, tree lopping, grazing, and stem cutting are the major forms of disturbance. Easily accessible *Quercus* spp., which also have high calorific and utility values, were the most affected species due to overexploitation (Table 5). Trees were indiscriminately lopped for fodder and cut down for fuelwood extraction. The climax communities of the Western Himalaya are characterized by the dominance of one or the other species of *Quercus* spp. (Awasthi et al. 2003). These forests are not only intricately associated with the hydrological balance but also form the life support system for the local inhabitants (Singh and
| Botanical name                  | Local name | Family   | Utility values | Calorific value (kJ g\(^{-1}\) dry weight) | Ranking\(^{b)}\) |
|-------------------------------|------------|----------|----------------|--------------------------------------------|------------------|
| *Quercus leucotrichophora*    | Banj       | Fagaceae | FW, F, HA, AI, BL | 24.0\(^{c)}\) | 1 | 1 |
| *Quercus floribunda*          | Moru       | Fagaceae | FW, F, HA, AI, BL | 22.92\(^{d)}\) | 2 | 2 |
| *Carpinus viminea*            | Chamkharik| Corylaceae | FW, F, HA, BL | 20.51\(^{e)}\) | 3 | – |
| *Quercus semecarpifolia*      | Kharsu     | Fagaceae | FW, F, HA, AI | 23.82\(^{f)}\) | 4 | 3 |
| *Abies pindrow*               | Raga       | Pinaceae | FW, T, HA | 19.17\(^{g)}\) | 5 | 4 |
| *Betula alnoides*             | Saud       | Betulaceae | FW | 19.65\(^{h)}\) | 6 | 7 |
| *Ulmus wallichiana*           | Emrohi, chamar | Ulmaceae | FW, F | – | 7 | – |
| *Neolitsea pallens*           | Pinna      | Lauraceae | FW, F | – | 8 | 11 |
| *Alnus nepalensis*            | Utees      | Betulaceae | FW | 15.29\(^{i)}\) | 9 | 6 |
| *Fraxinus micrantha*          | Angu       | Oleraceae | FW, F, HA, T | 21.45\(^{j)}\) | 10 | 3 |
| *Lyonia ovalifolia*           | Anyar      | Ericaceae | FW | 18.05\(^{k)}\) | 11 | 8 |
| *Persea spp*                  | Kaul       | Lauraceae | FW, F, HA | 19.64\(^{l)}\) | 12 | 9 |
| *Aesculus indica*             | Pangar     | Hippocastanaceae | FW | 18.60\(^{m)}\) | 13 | – |
| *Taxus baccata*               | Thuner     | Taxaceae | F, M, AI | 17.36\(^{n)}\) | 14 | 6 |
| *Pinus roxburghii*            | Chir/ Kulain | Pinaceae | FW, T, HA, AI, BL | 23.17\(^{o)}\) | 15 | 5 |
| *Pyrus pashia*                | Melu       | Rosaceae | FW, F, Fr | 19.50\(^{p)}\) | 16 | 12 |
| *Daphniphyllum himalense*     | Ratnalu    | Daphniphyllaceae | FW, HA | 18.66\(^{q)}\) | 17 | – |
| *Rhododendron arboreum*       | Burans     | Ericaceae | FW, FI | 21.54\(^{r)}\) | 18 | 10 |
| *Juglans regia*               | Akhroot    | Juglandaceae | FW, AI, HA, Fr | 22.51\(^{s)}\) | 19 | – |
| *Fraxinus xanthoxyloides*     | Thelka     | Oleraceae | FW, F | – | 20 | – |
| *Quercus glauca*              | Haring     | Fagaceae | FW, F, HA, AI, BL | 23.50\(^{t)}\) | 21 | – |
| *Ilex dipyrena*               | Kanel      | Aquifoliaceae | FW, HA | – | 22 | – |
Sustainability of these forests depends greatly on their productivity, resilience and human activities (Awasthi et al. 2003). Scientific studies suggest that the plant community structure is greatly influenced by disturbances in the forests (Yadav and Gupta 2006). Disturbances ultimately cause canopy gaps and reduce leaf fall; hence, they negatively affect the return of nitrogen to the soil and increase dryness in the forest (Singh et al. 1984a) and consequently lead to poor regeneration of the forest trees.

**Conclusion**

Lack of employment opportunities and low income are the major causes for rural people’s dependency on forests for their livelihood. This dependency is causing degradation of forests and is forcing people to migrate to cities in search of jobs. As agricultural and livestock productivity is sustained by inputs derived from forests, continued depletion of forest reserves in the long run will result in poor returns from agriculture and dairy farming. In hilly areas, to date the domestic sector is the major energy-consuming sector, which is largely dependent on fuelwood. In the study areas, 81–86% of fodder is also extracted from nearby forests. Increased resource dependency on surrounding conventional forests has affected the status of most of the preferred species.

Fodder and fuelwood plantations should be established on terraced land under an agro-silvicultural system and on community land. An effective method of eco-restoration incorporating involvement by local people is needed so that pressure on the forests can be reduced. Design of technology jointly by biological, physical, and social science researchers will resolve this issue. A proper understanding of the socioeconomic necessities of the population is essential. Attempts should be made to establish a local framework for generating a sustainable forest economy.

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